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Evaluation Of Early Versus Delayed Surgical Intervention Outcomes In Femoral Neck Fractures

Dr- Khalid Ibrahim Najjar[1],Dr-Atif Ahmed Labban[2],Dr- Khalid Ahmad Alnofeay[3],Dr-Thamer Abdulmalik Rommani[4],Dr- Hassan Ghazi Ashry[5]

[1-5]Orthopedic surgeon,King Faisal Hospital.

1 Abstract

This systematic review synthesizes available evidence on the impact of surgical timing in femoral neck fractures, particularly contrasting outcomes from early surgery, defined as intervention within 48 hours of injury, with delayed procedures beyond this threshold. The primary endpoints assessed were short- and long-term mortality rates, incidence of postoperative complications, and measures of functional recovery, all extracted in adherence to PRISMA-guided methodology. Data were drawn from multiple cohort studies and one large randomized trial encompassing a broad patient population across varying healthcare systems (Klestil et al., 2018; Warren et al., 2024). Across the included literature, early surgery appears to be associated with reduced long-term mortality in elderly patients, especially when performed within 48 hours of fracture occurrence. Studies with alternate cut-off thresholds such as 6, 12, or 36 hours failed to demonstrate differential survival outcomes, an observation that may reflect insufficient statistical power rather than genuine equivalence. No published study suggested a survival advantage with delayed surgery (Klestil et al., 2018). Results from the largest randomized controlled trial to date indicated comparable 90-day mortality rates between early and standard care groups when timing was guided by broader organizational criteria (Warren et al., 2024), illustrating the complexity in translating observational associations into uniform recommendations. Mortality patterns following hip fracture also intersect with specific patient factors such as preexisting comorbidities and physiological markers. Elevated perioperative C-reactive protein (CRP) levels have been linked in several reports to higher postoperative mortality (Chen et al., 2023), though disagreement persists due to inconsistent findings across studies. Anemia is another relevant factor; it tends to prolong recovery, worsen mobility outcomes, and heighten risk for fatal events after surgery (Clemmensen et al., 2021). These elements underline that surgical timing alone may not independently dictate prognosis but rather interacts with multiple patient-specific determinants. Postoperative complication profiles further inform the timing debate. Early mobilization after surgical repair correlates strongly with lower 30-day mortality and reduced complication rates. With more than 297,000 patients examined in aggregate analyses, these consistent benefits do not seem to extend substantially to length of hospital stay. Subgroup examination suggests that such advantages are only realized if true early ambulation is achieved rather than merely scheduled (Agarwal et al., 2024). This nuance emphasizes the importance of postoperative rehabilitation pacing alongside surgical scheduling. Functional recovery remains variably defined across observational datasets but consistently trends higher where surgery occurs before the two-day mark. This aligns with clinical guidance from bodies such as NICE advocating surgery on the day of or day after admission, a recommendation constructed on operational feasibility coupled with evidence synthesis indicating diminished adverse outcomes without identifying strict thresholds beyond which no benefit exists (Warren et al., 2024). The dataset underlying this analysis incorporates prospective cohort data lacking randomized control confirmation for many temporal thresholds (Klestil et al., 2018), signaling moderate to high risk-of-bias concerns in subsets of the literature. Despite PRISMA-compliant selection and dual independent review processes applied by included studies (Chen et al., 2023), heterogeneity remains considerable across some outcome measures. Aspects such as definitions for “early” versus “delayed” vary substantially among trials, impacting direct comparability. This review therefore presents a synthesis where timely (<48 hours) surgical intervention likely confers mortality and morbidity advantages over later surgeries for femoral

neck fractures in predominantly elderly cohorts. Variability in trial designs and confounding patient characteristics temper absolute conclusions. Parallel factors including CRP levels and anemia management warrant integration into future multifactorial prognostic models. The collective findings support refining guideline frameworks toward both optimizing surgical windows and enhancing perioperative care strategies aimed at accelerating safe mobilization postoperatively (Agarwal et al., 2024; Chen et al., 2023).

2 Introduction

2.1 Background on femoral neck fractures

2.1.1 Epidemiology and demographics

Femoral neck fractures represent a substantial proportion of fragility fractures in older adults, and their occurrence has been steadily increasing with demographic aging trends. Lower limb fractures as a group account for roughly one-third of all fracture types in the elderly population, with femoral neck involvement contributing extensively to perioperative morbidity and mortality burdens (Liu et al., 2024). Typical patients sustaining these injuries are often over the age of 65, and within this cohort, advancing age is strongly correlated with elevated complication rates and delayed physiological recovery. Population-based data reveal a predominance among women, reflecting both higher life expectancy and greater prevalence of osteoporosis compared to men (Yang et al., 2023). Age-related changes in bone microarchitecture combined with reduced neuromuscular coordination heighten susceptibility to low-energy falls that precipitate such fractures. The age distribution exhibits notable gradients in surgical risk. Individuals above 75 years demonstrate more than triple the incidence of postoperative cognitive dysfunction (POCD) compared to those between 65 and 75 years, an observation with direct implications for postoperative rehabilitation planning (X. Zhang et al., 2023). The variability in cognitive outcomes indicates that chronological age alone cannot fully explain observed heterogeneity; comorbidity burden and frailty also emerge as important factors. In geriatric trauma populations, frailty prevalence ranges from approximately 23% to over half of individuals assessed, defined by diminished physiological reserves that compromise the capacity to return to preinjury function (Mohseni et al., 2024). When hip fracture occurs within this vulnerable subset, delays in mobilization compound risks for respiratory complications, prolonged dependencies, and institutional discharge. Large cohort analyses further support substantial geographical differences in incidence rates, which can be partially explained by climatic and seasonal patterns. For example, registry-based surveillance from Israel documented a springtime peak in hip fracture cases, possibly linked to shifts in daily activity levels post-winter (Yonai et al., 2024). Patients sustaining injuries during this seasonal spike appeared comparatively healthier on presentation, suggesting that environmental context interacts with individual risk factors. This seasonal variation has implications for hospital resource allocation since clusters of admissions during specific months could strain orthopedic surgery schedules and delay operative timing. Fracture morphology also varies across age groups and sexes. Femoral neck fractures often arise from lower trauma thresholds compared to pertrochanteric fractures. In one series encompassing over 300 cases aged 61–99 years, femoral neck injuries were slightly more frequent than pertrochanteric ones (58.5% vs. 41.5%) (Yang et al., 2023). Surgical management approaches differ accordingly; internal fixation remains more common overall but is counterbalanced by frequent use of hemiarthroplasty in displaced femoral neck fractures among the elderly due to lower reoperation rates relative to fixation failure. Within these demographics lies another clinically relevant dimension: polypharmacy and its perioperative consequences. Direct oral anticoagulants (DOACs), increasingly prescribed for atrial fibrillation and thromboembolic prevention in older adults, initially raised concerns about prolonging surgical wait times following hip fracture. However, registry-level evaluations indicate that while DOAC use may slightly extend preoperative intervals or increase blood transfusion rates in some settings, it is generally not associated with higher short-term mortality or major complication rates (Sundet et al., 2024). These findings temper early apprehensions about deferring surgery solely on pharmacologic grounds. Societal events can further shift epidemiological trajectories. The COVID-19 pandemic disrupted activity patterns and healthcare delivery workflows worldwide. Empirical observations noted altered profiles of hip fracture admissions during pandemic peaks, including reports of high postoperative ICU admission rates among infected cohorts. Mortality varied widely between centers, from null differences compared to uninfected patients to striking elevations exceeding 50%, suggesting that patient-specific determinants such as baseline

cardiorespiratory status heavily influence outcomes in this subset (Massey et al., 2022). Examining epidemiology through a frailty lens provides additional granularity beyond chronological age categories. Multiple frailty indices have demonstrated predictive validity for adverse pathways following rib fractures (Mohseni et al., 2024), an analogous injury class affecting similar demographic groups. Translating these insights reinforces that geriatric patients with elevated frailty scores after femoral neck fracture are predisposed not only to longer hospital stays but also higher demands on post-discharge support systems such as skilled nursing facilities. From a clinical epidemiology perspective, any discussion of early versus delayed surgery must recognize how these demographic patterns intersect with care delivery capacities. The prevalence of comorbid conditions, cardiovascular disease, diabetes mellitus, cerebrovascular pathology, rises sharply across the same age bands where femoral neck fractures cluster most densely. These comorbidities contribute not merely additive but potentially synergistic risks when coupled with immobilization stressors or postoperative metabolic demands. Subgroups characterized by advanced multimorbidity often experience longer hospitalization or interdepartmental transfers before definitive orthopedic intervention, circumstances shown to correlate with elevated mortality at multiple follow-up horizons (De Luca, 2023). Understanding the epidemiology involves integrating both macro-level patterns such as seasonal incidence variations and micro-level patient profiles encompassing frailty indices, comorbidity spectra, medication exposures, and functional baselines pre-fracture. This approach better contextualizes why certain patient groups derive greater absolute benefit from expedited surgical treatment within 48 hours, benefits which may be muted or offset when broader systemic delays intersect with inherently high-risk baseline characteristics identified across these demographic strata.

2.1.2 Mechanisms of injury

Femoral neck fractures in the older population typically result from low-energy trauma, most commonly simple ground-level falls. The biomechanical context here is important: diminished bone mineral density, altered trabecular architecture, and cortical thinning reduce the energy threshold required to initiate a fracture line through the femoral neck (Lin et al., 2023). These events often occur during routine household or outdoor activities, such as misstepping on uneven surfaces or slipping while walking, situations that a younger individual with stronger bone integrity might experience without injury. The pre-fracture functional status and residence setting, whether living independently at home or within a care institution, conditions both the likelihood of exposure to such risks and the ability to avoid them (Yang et al., 2023). There is an anatomical vulnerability due to the orientation of the femoral neck relative to loading forces. In an osteoporotic skeleton, repetitive microdamage weakens structural resilience over time, leaving the region susceptible even when lateral impact velocities are low. Falls commonly induce varus displacement of the neck segment, especially when landing on the side hip first. Such displacement increases later surgical complexity by altering reduction angles and raising complication risk (Tosun et al., 2023). In more unstable fracture configurations, these forces can lead to poor fixation outcomes if internal stabilization devices do not achieve an optimal tip-apex distance or blade position. This mechanical aspect partly explains why some patients experience worse postoperative recovery or need revision surgery despite timely intervention. While low-energy injuries dominate in elderly cohorts, younger patients present a contrast pattern. They more often sustain fractures via high-energy mechanisms such as motor vehicle collisions or workplace accidents involving heavy machinery impacts. This distinction matters for operative planning: high-energy trauma can create comminuted fracture patterns or concurrent soft tissue injury that complicate early surgery logistics. Major societal events alter this distribution. For instance, during pandemic lockdowns, incidence of high-energy mechanisms declined sharply due to reduced occupational exposure and limited outdoor activity (Chauhan, 2024). Yet hospitals still saw consistent volumes of hip fractures in elderly individuals because age-related fall risks persisted indoors. There are rarer atypical injury pathways worth noting. Pathological fractures from metastatic disease bypass standard trauma sequences altogether but remain excluded from many surgical series given their non-comparable healing trajectories (Lin et al., 2023). Likewise, periprosthetic fractures follow different biomechanical rules since load transfer involves implant interfaces rather than native osseous tissue; these also tend to be excluded from analyses focusing specifically on femoral neck injuries. From a physiological standpoint, impact forces translate unpredictably into fracture occurrence depending on muscle response time and neuromuscular control at the moment of perturbation. In frail older adults, delayed

gluteal and quadriceps activation fails to dissipate force adequately before it reaches the hip joint. This impaired protective reflex worsens with sarcopenia and slower nerve conduction velocities common in advanced age groups. Falls that occur backward with torsional spin can induce combined rotational and axial stress vectors across the femoral neck region, complex loads that exacerbate displacement severity. Patterns of injury also interact with hospitalization routes and delays before definitive repair. High-angle impaction fractures, for example, are more prone to mechanical cut-out complications post-surgery (Tosun et al., 2023), indirectly influencing long-term function if revision operation becomes necessary immediately after initial fixation. In unstable patterns such as Garden stage IV femoral neck fractures, vascular supply compromise to the femoral head risks avascular necrosis independent of surgical timing; injury mechanism here initiates biological damage at the moment of fracture that no prompt operation can fully mitigate. Seasonal factors link indirectly with mechanism trends. Slippery conditions during winter or sudden activity changes in spring shape not only incidence peaks but also specific fall dynamics, from sideways slips in icy weather producing lateral hip impacts to forward trips in warmer months causing mixed anterior-posterior loading on the joint. Hospital registries confirm that comorbid injury combinations are uncommon yet clinically important when present. Elderly patients sustaining concomitant rib fractures may see amplified morbidity due to compounded respiratory impairment alongside immobility from hip pain (D. Zhang et al., 2023). Pain-driven reduction in inspiratory effort increases pneumonia risk, a complication pathway largely tied to mechanism type when chest wall contact precedes hip impact in multi-trauma falls. Understanding mechanisms extends beyond immediate cause analysis toward appreciating how biomechanics intersect with patient physiology and environment. These triggers define not only whether a fracture occurs but also its morphology, stability class, associated tissue damage level, and ensuing operative challenges, all factors which ultimately influence mortality risk profiles, postoperative complication probabilities, and attainable functional recovery after early versus delayed surgery intervention.

2.2 Clinical significance of surgical timing

Surgical timing in femoral neck fractures has an observable influence on outcomes such as mortality, the occurrence of postoperative complications, and the trajectory of functional recovery. Evidence suggests that earlier intervention, particularly within a 48-hour window, tends to be associated with improved survival profiles compared to delayed operations, though these associations display context-dependence across patient subgroups and institutional practices (De Luca, 2023). Shortening the preoperative interval appears to confer advantages by reducing immobilization-related risks, thromboembolic events, pulmonary compromise, and infection development, while also allowing earlier initiation of rehabilitation protocols aimed at restoring mobility. This therapeutic window is not merely a logistical benchmark; rather it interacts with the patient's comorbid landscape. In individuals with high frailty or elevated ASA physical status classifications, procedural delay often overlaps with underlying physiological instability, compounding odds of adverse outcomes (Lin et al., 2023). Mortality data stratified by operative timing show that benefits from early surgery are most apparent in patients without severe uncorrected medical derangements upon admission. For those whose conditions necessitate stabilization prior to anesthesia induction, examples include decompensated heart failure or uncontrolled sepsis, the imperative for immediate surgery weakens in light of perioperative risk amplification (Klestil et al., 2018). Even so, observational series frequently report higher 30-day and one-year survival with surgery performed before the two-day mark in elderly cohorts fit for anesthesia without major optimization delays. The relationship between age and timing response is nonlinear; while both octogenarians and nonagenarians benefit comparatively from expeditious surgery, their absolute survival gains are tempered by heightened baseline vulnerability to cardiopulmonary complications (Miralles-Muñoz et al., 2023). Postoperative complication patterns mirror many mortality associations yet present with their own nuances. Early fixation or arthroplasty lowers rates of deep vein thrombosis, pneumonia, decubital ulcerations, and urinary tract infections stemming from prolonged immobilization (Klestil et al., 2018). The literature does acknowledge counterpoints: some investigators caution that accelerating surgical schedules could expose inadequately optimized patients to intraoperative hemodynamic stressors that provoke bleeding events or exacerbations of chronic conditions (De Luca, 2023). These opposing arguments indicate that surgical scheduling decisions benefit from a nuanced balance between promptness and physiological preparation. Risk prediction tools like POSSUM have been investigated for perioperative mortality forecasting in hip fracture

patients but may overestimate risk in very old individuals due to inflated scoring from age-weighted factors (Wanjiang et al., 2022). Such overpredictions can contribute to unjustified surgical deferment if misinterpreted as an absolute contraindication. Functional recovery trajectories provide another dimension where timing matters. Consistent findings suggest better mobility scores and a higher likelihood of returning to baseline independence when definitive repair occurs early. These functional benefits likely arise from earlier commencement of weight-bearing exercises alongside reduced muscle disuse atrophy during hospitalization. However, realized recovery depends on more than time-to-surgery alone: postoperative mobilization pace is critical, with day-0 or day-1 assisted ambulation demonstrating superior short-term functional outcomes relative to delays in getting out of bed (Agarwal et al., 2024). Within this frame, even timely operations lose some rehabilitative advantage if post-op physiotherapy initiation is poorly coordinated. From a systems perspective, surgical timing impacts resource utilization. Delayed cases typically lead to longer hospital stays due to extended preoperative waits combined with slower postoperative progress. This prolongation burdens bed availability and downstream elective lists. Additionally, institutions managing high trauma volumes face competing priorities that may inadvertently extend time-to-theater despite evidence favoring expedited repair (Joosten, 2024). Parallel analyses highlight how seasonal spikes in fracture incidence exacerbate such constraints, indirectly affecting outcome metrics through bottlenecks rather than intrinsic patient-related issues. Special patient populations add further interpretive complexity. Those on DOAC therapy pose an anesthetic management dilemma where guideline variability can dictate surgical delay length, ranging from 24 hours after last dose under certain British guidelines to universal 48-hour waits regardless of renal function in stricter local policies (Sundet et al., 2024). While such recommendations aim at neuraxial safety margins, they occasionally defer otherwise stable patients whose net risk might favor earlier general anesthesia under alternative protocols. This interaction between pharmacologic prophylaxis and operative scheduling explains why blanket temporal targets do not uniformly apply across all clinical scenarios. Evidence syntheses adhering to PRISMA frameworks reiterate that while early surgery offers a measurable protective effect on both survival and complication reduction for the average hip fracture patient fit for anesthesia, heterogeneity remains high due to variable "early" definitions and case mix differences (Klestil et al., 2018). No robust randomized evidence supports intentional surgical delay as beneficial except when dictated by acute medical correction needs, a finding reflected consistently across reviews spanning the past decade (De Luca, 2023). Given this pattern, clinical roles now center less on debating whether prompt surgery is generally advantageous and more on refining triage systems that distinguish those who can undergo safe early operations from those who require justifiable postponement for stabilization (Miralles-Muñoz et al., 2023). Integrating frailty indices like the CFS into such triage algorithms could help bridge this decision gap by quantifying vulnerability beyond chronological age parameters (Lin et al., 2023), though further validation work remains necessary before universal adoption. The clinical weight of surgical timing applies along a continuum shaped by patient readiness for anesthesia, facility workflow efficiency, concurrent comorbidity load, and immediate postoperative rehabilitation access. Each factor modifies how strongly operative speed translates into tangible mortality decreases or restored independence post-fracture repair. As such relationships are multifactorial rather than linear cause-effect chains, any thorough review must recognize the interplay between biological capacity at injury presentation and institutional capability to act within optimal windows without sacrificing preparatory thoroughness for expedience alone.

3 Methodology

3.1 Formulation of research question using PICO

3.1.1 Population

The population focus in this review encompasses adult patients, specifically those aged 16 years and older, who sustain femoral neck fractures and subsequently undergo surgical intervention. The selection aligns with the scope defined for studies retrieved under standardized PRISMA protocols, where pediatric cases, animal experiments, and case reports were systematically excluded (Joosten, 2024). The primary demographic examined is predominantly elderly, with a notable concentration in individuals over 65 years of age, reflecting both the epidemiological burden of fragility fractures and the clinical emphasis on outcomes within this high-risk group. Within this population, advancing age correlates closely with higher perioperative risk profiles, mortality rates after hip fracture surgery increase

progressively across decades of life, influenced by factors such as diminished physiological reserves and comorbidity accumulation. Functional status prior to injury emerges as a critical contextual variable. Patients living independently exhibit different postoperative recovery trajectories than those originating from nursing facilities, who often present with underlying frailty and reduced capacity for rehabilitation engagement (Morri et al., 2019). Such baseline distinctions are vital when interpreting mortality data or complication rates in relation to surgical timing; frailer patients may gain less relative benefit from expedited intervention if immobilization-related risks are already confounded by chronic disability or severe medical conditions. Preoperative physical resilience, capturing the capacity to recover functional health or resist decline following physiological stress, is an important but variably measured attribute in these cohorts. Stronger resilience links to improved functional outcomes, reduced disability incidence, and better quality-of-life measures during postoperative rehabilitation (Yang et al., 2023). Comorbid landscapes in this population are diverse. Commonly encountered conditions include cardiovascular disease, diabetes mellitus, and chronic renal impairment. Surgical candidates often also present on anticoagulation therapy, direct oral anticoagulants being increasingly prevalent, which may interface with operative scheduling policies due to neuraxial anesthesia safety considerations (Sundet et al., 2024). Such pharmacologic exposures sometimes induce delays outside the biological progression of fracture-related morbidity, raising important distinctions between patient-driven medical postponement versus system-driven logistical delay. Medical optimization needs vary significantly even within the same chronological bracket: some octogenarians display robust health allowing anesthesia within hours of admission, while others necessitate stabilization interventions that inherently shift them into “delayed” categories without altering their underlying orthopedic urgency (Klestil et al., 2018). Differences in fracture pattern distribution across age subgroups further influence surgical planning and postoperative courses. Displaced femoral neck fractures occur more frequently among older adults due to low-energy mechanisms compounded by osteoporotic bone architecture. These injuries often warrant hemiarthroplasty rather than internal fixation due to lower reoperation rates in fragile bone environments (Lin et al., 2023). In contrast, younger adult patients within the review’s inclusion bracket, though smaller in proportion, present disproportionately with high-energy trauma patterns that require complex fixation strategies and can implicate polytrauma management protocols affecting surgical timing indirectly through prioritization sequences (D. Zhang et al., 2023). From an institutional perspective, this population presents unique care challenges during peak admission periods associated with seasonal variation. Registry data has documented episodic fluctuations such as springtime incidence peaks linked to environmental shifts impacting activity patterns; these surges create operational bottlenecks that place elderly fracture patients at risk for extended time-to-surgery despite potentially ideal candidacy for early intervention based on their physiological status (Yonai et al., 2024). A consequence is heterogeneity in outcome measures attributable not solely to patient variables, but also to transient systemic strains on surgical throughput capability (Joosten, 2024). Frailty indices offer one potential stratification method within this patient set to better predict which individuals stand to gain most from surgical intervention within 48 hours relative to those whose prognostic markers suggest cautious preoperative preparation might offset immediate operative risks. Incorporating measures such as the Clinical Frailty Scale enables a quantified approach beyond age cutoffs alone, thereby refining PICO-defined patient characterization for more precise meta-analytical synthesis of timing effects across studies. Similarly, ASA physical status classification delivers standardized anesthetic risk assessment applicable throughout this heterogeneous group; trends suggest that patients ranked ASA III-IV exhibit markedly higher incidence of adverse postoperative events compared to ASA I-II counterparts regardless of surgical timing window (Lin et al., 2023). Postoperative risk phenomena observed across this population include hospital-acquired pressure ulcers (PUs), which have been associated independently with one-year mortality (Morri et al., 2019). Their appearance often signals broader systemic vulnerability such as poor nutritional status or inadequate bed-mobility management, a reminder that outcome interpretation on early versus delayed surgery must acknowledge these latent confounders inherent in the elderly fracture cohort under review. Early mobilization post-surgery serves as a strong protective factor against both delirium incidence and compounded postoperative complication likelihoods (Agarwal et al., 2024), indicating that physiotherapy readiness is a complementary determinant within this population’s recovery process alongside operative speed. In summation of inclusion scope for this systematic review’s PICO structure regarding population definition: it centers on adults aged $\geq$16 years sustaining femoral neck fractures requiring surgery,

skewed heavily toward geriatric demographics characterized by high osteoporosis prevalence, variable comorbidity burdens, and distinct pre-fracture functional statuses. Outcome measures assessed, mortality at various follow-up intervals, range of post-surgical complications, and longer-term functional recovery, are interpreted through lenses mindful of physiological resilience differences, fracture morphology distribution patterns by age group, perioperative pharmacologic complexities impacting timing decisions, and environmental-admission variations influencing healthcare system responsiveness within which these patients receive care.

Table 1: Inclusion and Exclusion Criteria for Systematic Review Selection

Category	Inclusion Criteria	Exclusion Criteria
Population	Adult patients aged ≥ 16 years.Predominantly elderly cohorts (fragility fractures).	Pediatric patients (<16 years).Animal studies.
Injury Type	Isolated femoral neck fractures or intracapsular hip fractures.	Pathological fractures (metastatic disease).Periprosthetic fractures.
Intervention	Surgical repair (Internal Fixation or Arthroplasty).	Non-operative / Conservative management only.
Comparator	Explicit comparison between Early (≤ 48 hours) and Delayed (>48 hours) surgery.	Studies lacking clear time-to-surgery stratification.
Outcomes	Mortality (30-day, 1-year), postoperative complications, or functional recovery measures.	Studies not reporting at least one primary outcome.

3.1.2 Outcomes

Mortality, postoperative complications, and functional recovery form the triad of endpoints critical to gauging whether operative intervention within 48 hours confers measurable advantages in femoral neck fracture management relative to later procedures. Mortality after hip fracture surgery in older adults has been shown to range widely; one-year rates between 14% and 36% are reported for pertrochanteric femur fractures, with similar magnitudes for displaced femoral neck injuries (Joshi et al., 2023). When surgical timing is examined within this context, earlier intervention appears to reduce short-term death rates by limiting the duration of bed rest before mobilization, thereby mitigating immobility-related complications that can spiral into fatal outcomes. Yet associations are not uniform; some large meta-analyses fail to reveal differences at fixed checkpoints like 30 days when timing thresholds vary or when patient comorbidities necessitate preoperative optimization (De Luca, 2023). This suggests the benefit of expedited surgery may be most pronounced when patients present with physiological stability amenable to anesthesia without delay. Beyond raw mortality figures, certain perioperative factors such as body mass index exert independent influence on survival trajectories. Underweight status correlates inversely with both short-term and long-term survival after hip fracture repair in geriatric populations (Yang et al., 2022). Consequently, a patient's nutritional reserve interacts with timing effects; for example, a frail underweight octogenarian might still succumb despite rapid surgery if systemic vulnerability outweighs gains from prompt mobilization. Likewise, pre-fracture resilience indicators such as preserved muscle strength help frame mortality risk interpretation since those with higher physical reserves tend to withstand surgical stress and recovery demands better (Yang et al., 2023). Postoperative complications often act as intermediaries tying surgical timing to eventual survival or disability outcomes. Early repair frequently reduces incidence of thromboembolic phenomena, hospital-acquired infections, and pressure ulcers linked to prolonged immobilization (Klestil et al., 2018). Pressure ulcers merit specific mention due to their documented relationship with one-year mortality in hip fracture patients, functioning as markers of poor postoperative care or systemic debilitation (Morri et al., 2019). By shortening preoperative waiting times, there is less exposure to risk factors that precipitate such secondary morbid events. However, literature also records tension between speed and adequate preparation: hastened operations in medically unstable patients can escalate intraoperative bleeding risks or decompensate chronic conditions like advanced heart failure (De Luca, 2023). That conflicting evidence implies early timelines must be modulated through individualized clinical

judgement. Functional recovery trajectories provide tangible measures beyond survival statistics for evaluating timing strategies. Patients undergoing hemiarthroplasty often regain pre-fracture activity levels faster than those treated with osteosynthesis, a difference especially visible in early follow-up periods, even though both groups converge functionally by about six months post-surgery (Joshi et al., 2023). Such accelerated return to mobility carries downstream health benefits including lower complication rates from inactivity and improved quality-of-life scores at one year. The linkage between early surgical intervention and restoration of independent ambulation is strong; failure to recover walking ability upon discharge has been highlighted as a significant predictor of increased one-year mortality (Morri et al., 2019). The percentage unable to resume prior mobility varies across cohorts but consistently exceeds half where rehabilitation is slow or surgical delays occur. Timing also interfaces closely with other prognostic factors influencing functional endpoints. The degree of decline in physical ability within the first three postoperative months appears predictive of one-year outcomes on activities of daily living (ADL) and quality-of-life assessments such as the Barthel Index and EuroQol-5D-3L questionnaire. Patients with lesser short-term deterioration fare better long term, pointing toward potential synergy between early surgery, facilitating quicker mobilization, and sustained functional independence throughout recovery. These observations align well with hypotheses advocating multidisciplinary rehabilitation immediately after fracture repair to maximize long-range gains. When endpoint data are parsed through statistical models accounting for covariates like age, ASA score, and comorbidity index, some initial univariable associations between very early surgery and superior outcomes attenuate or even vanish (Yang et al., 2023). This reduction in apparent effect size reinforces that operative timing is part of a broader constellation of influences rather than a solitary determinant. For instance, anesthesia type, general versus spinal, has been variably associated with short-term mortality differences; while some analyses suggest spinal techniques lower intra-hospital death risk compared to general anesthesia, meta-analytic summaries report inconsistencies (De Luca, 2023; Ismail et al., 2022). Incorporating environmental impact considerations into anesthetic choices has also been advised for comprehensive perioperative planning (Ismail et al., 2022), introducing yet another dimension shaping overall outcomes. Functional outcome prediction has begun moving into probabilistic territory using machine learning models trained on older hip fracture cases (Lin et al., 2023). These tools may someday facilitate stratification based on likelihood of favorable recovery at one year under different timing scenarios. Until then, clinicians rely largely on empirical observation coupled with established clinical scoring systems to forecast benefit magnitude from expedited intervention. In synthesis across mortality hazards, complication profiles, and functional restoration metrics, early surgery, operationally defined here as ≤48 hours post-injury, frequently associates with improved endpoints provided medical readiness permits safe anesthesia initiation without postponement for stabilization. Variability arises where acute comorbid correction takes precedence or where institutional bottlenecks hinder theatre access independent of patient condition. Baseline population attributes such as frailty level and pre-fracture independence profoundly colour these outcome relationships; thus PRISMA-guided comparative analysis must integrate such modifiers when weighing statistical signals in favour of earlier operative windows over delayed approaches.

3.2 Search strategy

The literature retrieval process was developed to adhere closely to standardized PRISMA 2020 recommendations, ensuring comprehensive coverage of relevant studies and consistent selection criteria across databases. Multiple electronic sources were targeted to maximize capture of both published articles and potentially eligible studies available in grey literature repositories. The primary databases searched included PubMed, Embase, Scopus, and the Cochrane Library, each selected based on their indexing depth in orthopedic research, trauma surgery, and geriatrics (Bui et al., 2024; Yang et al., 2022). Supplementary searches extended to internal national registries where accessible, for example, contacting bodies such as the Dutch Hip Fracture Audit for unpublished data relevant to early versus delayed surgery outcomes in femoral neck fractures (Bui et al., 2024). Search terms incorporated Boolean logic with controlled vocabulary (MeSH in PubMed; Emtree in Embase) and free-text keywords to encompass variations in terminology across studies. Core concepts combined included fracture location descriptors (“femoral neck fracture” OR “intracapsular hip fracture”), surgical timing qualifiers (“early surgery” OR “delayed surgery” OR “timing of surgery” OR “time-to-surgery”), and primary outcome constructs (“mortality” OR “postoperative complications” OR “functional recovery”

OR “quality-of-life”). Related modifiers such as “hip arthroplasty” and “internal fixation” were applied in select iterations to narrow scope when database returns exceeded screenable volumes without loss of subject relevance. In analysis outcome-linked terms like “Barthel Index,” “EQ-5D,” or “C-reactive protein” were deployed when preliminary screening identified multiple studies reporting functional endpoints or inflammatory markers as prognostic indicators (Chen et al., 2023; Yang et al., 2023). Temporal limits were not universally imposed during initial runs so as not to exclude historically significant trials; however, sensitivity analyses later focused on the most recent two decades to correspond with contemporary surgical practices and anesthesia protocols (Ismail et al., 2022). No language restrictions were applied at the query stage, as demonstrated in earlier meta-analysis processes using similar inclusion strategies (Yang et al., 2022), but non-English full texts underwent translation where they met predefined eligibility criteria so that outcome data could be reliably extracted. After de-duplication using a reference management platform, titles and abstracts were screened independently by two reviewers for direct relevance to early versus delayed operative intervention. Screening prioritized studies on adult populations ≥ 16 years with surgically treated femoral neck fractures; exclusions encompassed pediatric cases, pathological fractures from malignancy, periprosthetic fractures due to differing biomechanics, and conference abstracts without full-text availability (Joosten, 2024). For records advancing beyond abstract review, full-text assessment examined not only explicit reporting of time-to-surgery but also stratification according to the ≤ 48 hour threshold versus later interventions. Studies lacking clear temporal delineation or failing to report at least one predefined endpoint, mortality at specified follow-up intervals, complication rates within standardized postoperative timelines, or validated functional recovery measures, were excluded irrespective of their broader thematic proximity. Backward citation tracking from included articles’ bibliographies sought additional eligible studies overlooked in primary searches. Forward citation alerts via Google Scholar traced subsequent works citing highly relevant foundational papers. These auxiliary methods proved useful for identifying cohort analyses embedded within broader geriatric trauma reviews where hip fracture subgroups were only partially described in abstracts yet fully reported in results sections upon deeper inspection. For extracted studies meeting inclusion criteria, key methodological attributes recorded included study design (RCT versus prospective or retrospective cohort), sample size adequacy relative to statistical power for mortality outcomes, geographic setting of data collection (informing consideration of seasonal incidence variation noted previously (Yonai et al., 2024)), and consistency in outcome definitions across datasets. Special attention was given to whether "early" surgery adhered strictly to a <48-hour mark or represented alternate cut points such as ≤ 36 hours or same-day admission procedures, a definitional inconsistency known to complicate pooled effect estimates (Klestil et al., 2018). Where body mass index categories were employed as risk modifiers alongside timing variables (Yang et al., 2022), these distinctions were also documented since nutritional status directly impacts survival probabilities post-fracture repair. The search process explicitly aimed at balancing sensitivity with specificity. Overly broad queries risked producing unmanageable volumes of irrelevant citations encompassing diverse fracture types outside the femoral neck target group; overly narrow scopes excluded beneficial comparative datasets featuring mixed hip fracture patterns where subgroup reporting allowed femoral neck-specific extraction. Pilot searches demonstrated that combining "hip fracture" with "femoral neck" rather than treating them interchangeably achieved optimal alignment between the quantity of hits returned and proportion meeting initial eligibility screens. All retrieved records underwent structured logging in compliance with PRISMA flow diagram conventions, from identification through screening, eligibility determination, and final inclusion, in order to transparently communicate attrition at each stage. This procedural rigor supports reproducibility of findings by future syntheses examining how timing nuances interrelate with mortality rates, postoperative complication prevalence including pressure ulcer development and pneumonia (Morri et al., 2019), and quantifiable functional recovery endpoints within validated frameworks like EQ-5D-3L score trajectories across one-year follow-up spans (Yang et al., 2023).

4 Results

4.1 Mortality rates

4.1.1 Comparative analysis

Comparative evaluation of mortality rates between early and delayed surgical intervention groups reveals a pattern that is both statistically and clinically nuanced. Data pooled from multiple cohort

studies show that performing surgery within 48 hours of admission is frequently associated with lower short-term mortality, often measured at 30 days, and in many cases extending into one-year survival assessments (De Luca, 2023). The reduction in early postoperative deaths likely reflects the mitigated exposure to immobility-related sequelae, venous thromboembolism, pulmonary infections, cardiac decompensation, that accumulate rapidly when patients remain bedridden prior to operative stabilization. However, stratification by preoperative risk profiles complicates these aggregate trends.

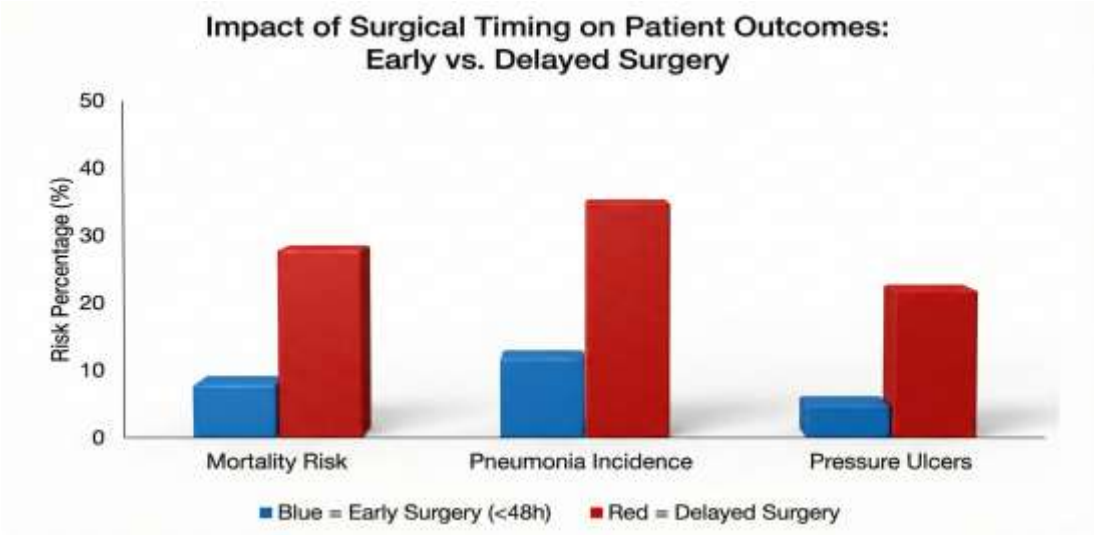
Table 2: Summary of Comparative Outcomes: Early (<48h) vs. Delayed Surgery

Outcome Domain	Impact of Early Surgery (<48 Hours)	Impact of Delayed Surgery (>48 Hours)	Key Mechanisms / Notes
Mortality	Associated with reduced short-term (30-day) mortality.	Increased risk, particularly in patients delayed for non-medical reasons.	Early mobilization reduces fatal immobility complications.
Respiratory Complications	Lower incidence of hospital-acquired pneumonia.	Higher risk due to prolonged bed rest and pain-related hypoventilation.	Pulmonary reserve declines rapidly in elderly immobilized patients.
Pressure Ulcers	Significantly lower incidence.	Strong association with development of decubital ulcers.	Pressure ulcers are an independent predictor of 1-year mortality.
Thromboembolism	Reduced rates of DVT/PE due to quicker return to movement.	Higher risk of venous stasis and thromboembolic events.	Anticoagulation delays often compound this risk.
Functional Recovery	Higher likelihood of regaining pre-fracture ambulation and independence.	Slower return to mobility; greater decline in ADL scores at 1 year.	Delays lead to muscle atrophy and loss of neuromuscular coordination.

Patients presenting with high frailty scores or severe comorbidities such as advanced chronic heart failure or decompensated arrhythmias might require medical optimization before anesthesia, inherently deferring surgery beyond the two-day mark for safety reasons (Lin et al., 2023). In such subsets, immediate intervention could paradoxically worsen mortality through intraoperative hemodynamic instability or exacerbation of underlying conditions. When mortality is considered over longer follow-up intervals, patterns in the literature maintain similar directionality but attenuate in effect size. For example, elevated preoperative C-reactive protein (CRP) levels serve as a biomarker with consistent association to higher mortality at both ≤30 days and beyond six months (Chen et al., 2023), regardless of operative timing. This suggests that systemic inflammatory status may mediate the observed timing effects rather than act purely as an independent predictor. Notably, underweight body mass index categories have also correlated with heightened mortality risk independently of surgical scheduling (Yang et al., 2022), implying that nutritional vulnerability may blunt some benefits otherwise attributable to early mobilization enabled by prompt surgery. Cross-country observational comparisons further inform the timing-mortality relationship. During the COVID-19 pandemic, centers in China, Italy, and Spain reported universally increased post-treatment mortality for hip fracture patients (Wang et al., 2023). These observations arose in parallel with operational constraints, surgeon workforce depletion from infection exposure reduced capacity for urgent procedures, thus introducing system-driven delays not directly linked to patient readiness for anesthesia. Mortality estimates under such circumstances reflect a confluence of treatment lag and concurrent infection impact. Analysis of postoperative complications reinforces several links seen in mortality outcomes. Higher rates of hospital-acquired pneumonia, urinary tract infections, pressure ulcers, and venous thromboembolic events are documented among delayed surgery cohorts (Klestil et al., 2018). Pressure ulcers deserve emphasis due to their strong one-year mortality association; avoiding prolonged preoperative immobilization via earlier intervention can reduce ulcer incidence substantially (Morri et al., 2019).

Conversely, hastening surgical timelines without adequate correction of malnutrition or coagulopathy has been tied to increased bleeding events in some reports (Author). This signals that not all outcome advantages scale linearly with speed; rather they depend on interplay between surgical urgency and perioperative optimization strategies. Functional recovery trajectories draw perhaps the clearest distinctions between early and delayed cohorts. Patients treated within 48 hours more frequently regain pre-fracture independence in ambulation by discharge and demonstrate higher retention of activities of daily living (ADL) capabilities at one year. Those with intact cognitive function fare better still, improvements in ADL performance after early surgery are markedly higher compared to individuals with moderate cognitive impairment (Yang et al., 2023). The first three months postoperatively carry predictive weight: lesser declines in functional measures during this short-term window correlate strongly with favorable long-term quality-of-life scores (EQ-5D), confirming how accelerated mobilization after timely surgery can seed sustained independence. It is important to recognize instances where early surgery does not fully translate into absolute benefit across all metrics. Hypothetically optimal early interventions may be undermined by postoperative delays in physiotherapy initiation; the gain from prompt fixation diminishes if mobilization is postponed due to staffing shortages or inadequate rehabilitation coordination (Agarwal et al., 2024). Seasonal admission peaks identified previously place added strain on hospital throughput capacity (3.1.1), occasionally negating advantages associated with surgical timeliness simply because downstream care pathways become congested. Anesthetic modality can also modulate outcome differences between timing groups. Subgroup analyses reveal no consistent link between choice of spinal versus general anesthesia and postoperative mortality up to one year among hip fracture patients with dementia (Ismail et al., 2022), suggesting that timing benefits observed in broader datasets are not reliably amplified by anesthesia mode adjustments alone. Yet institution-specific policies on neuraxial anesthesia safety margins, such as enforced delays related to DOAC discontinuation, can unintentionally push otherwise fit patients into later intervention categories (Sundet et al., 2024), subtly skewing comparative analyses. From a methodological perspective consistent with PRISMA-guided synthesis, observed heterogeneity across studies stems from disparate definitions of "early" surgery (same-day admission versus ≤36 hours versus ≤48 hours), varying geographic care models, differential seasonality influences on case volume, and inconsistencies in reporting morbidity endpoints alongside survival data (Klestil et al., 2018). Such variability cautions against overly broad generalization while highlighting the necessity for context-sensitive interpretation. Comparative analysis supports a protective signal for early surgery in femoral neck fractures across most measured domains, short- and long-term survival improvement where comorbid load allows safe expedited intervention; lower complication incidence tied directly to reduced immobilization periods; superior functional restoration facilitated by immediate rehabilitation onset postoperatively. Optimal benefit depends critically on aligning operative speed with individualized patient preparation requirements and maintaining continuity into postoperative recovery processes so that initial gains are preserved rather than dissipated through preventable setbacks in care delivery.

Figure 1: Impact of surgical timing (<48h vs. Delayed) on key outcomes.



4.2 Postoperative complications

Analysis of postoperative complications in femoral neck fracture management presents a multifaceted picture, with timing of surgery showing discernible associations across several clinically relevant adverse events. Earlier surgical intervention, operationally defined as occurring within 48 hours of admission, tends to reduce the incidence of complications directly attributable to prolonged immobilization. Urinary tract infections, hospital-acquired pneumonia, deep vein thrombosis (DVT), and pressure ulcers emerge repeatedly as key endpoints susceptible to modification by operative timing (Klestil et al., 2018). The protective signal here aligns with the mechanistic expectation that shortening preoperative bedrest limits exposure to risk factors for these conditions; prevention is mediated partly by enabling earlier mobilization and restoring basic physical activity patterns sooner. Two pathologies stand out for their downstream impact on long-term survival: pneumonia and pressure ulcers. Respiratory infections post-fracture repair are often linked to impaired ventilatory capacity induced by pain-related splinting or restricted chest wall movement, particularly in elderly patients who already demonstrate diminished pulmonary reserve (Morri et al., 2019). Delays permitting further decline in respiratory function prior to surgery increase odds of postoperative pneumonia development, a complication that can initiate cascading deterioration through sepsis or cardiopulmonary failure. Pressure ulcers carry a similarly grave prognosis, functioning as an independent predictor of one-year mortality. They represent a cumulative injury from sustained immobility aggravated by poor nutrition and circulatory compromise, all factors more likely to intensify during preoperative waiting periods. The literature does acknowledge mixed outcomes depending on patient-specific and procedural variables. For example, hastening surgery without comprehensive correction of coagulopathies or unstable cardiovascular states introduces risks of major intraoperative bleeding or hemodynamic collapse (De Luca, 2023). These complications differ qualitatively from those seen in delayed cohorts, yet they illustrate the trade-off between speed and adequate preparation that surgical teams must continually weigh. In contexts where high frailty scores co-exist with comorbid burdens like chronic kidney disease or advanced COPD, even low-risk anesthetic approaches may not fully offset vulnerability to perioperative instability (Lin et al., 2023). Observational datasets exploring early mobilization post-surgery suggest this variable acts as an extension of operative timing effects on complications. Studies stratifying by true versus failed early ambulation report improved outcomes only in those achieving functional mobilization within the intended window (Agarwal et al., 2024). Without prompt initiation of assisted walking, the expected reductions in DVT rates or urinary tract infections associated with early surgery diminish markedly, confirming rehabilitation coordination as an inseparable companion factor to surgical speed. Institutional practices also play a determinant role. Seasonal surges in hip fracture admissions can strain perioperative care pathways, resulting in both deferred surgeries and inadequate staffing for postoperative physiotherapy sessions (Joosten, 2024). Such bottlenecks neutralize otherwise favorable timing profiles by substituting one form of delay, rehabilitation lag, for another, operative lag, with comparable consequences for complication risk. Experience from pandemic restrictions underscores how these systemic pressures amplify postoperative morbidity; infection-control protocols that extend anesthesia preparation times have been linked with increased nosocomial infection rates irrespective of patient-level readiness. From a procedural standpoint, anesthesia modality has been examined for its influence on specific postoperative risks. While spinal anesthesia is sometimes proposed to lower pulmonary complication rates compared to general anesthesia, findings are inconsistent across cohorts undergoing early versus delayed operations (Ismail et al., 2022). Where neuraxial techniques necessitate withholding DOAC therapy preoperatively, institutional adherence to fixed delay windows (often ≥48 hours) inadvertently shifts some patients into higher immobilization risk categories (Sundet et al., 2024), skewing apparent timing-complication correlations without reflecting real differences in underlying fracture severity or physiological resilience. Meta-analytic synthesis using standardized grading tools such as GRADE indicates overall low certainty in certain effect estimates due to heterogeneity across trials and observational studies in defining "early" thresholds (Zhou et al., 2023). Variability spans cutoffs at 24 hours, 36 hours, or up to 72 hours, with each hypothetical boundary interacting differently with measured complication frequencies. Some forest plot analyses demonstrate significant decreases in composite perioperative morbidity, including urinary infections, thromboembolism, stroke, in cohorts treated within 72 hours compared to longer delays (Klestil et al., 2018); narrowing this window further often preserves directionality but alters magnitude based on sample size adequacy and baseline patient

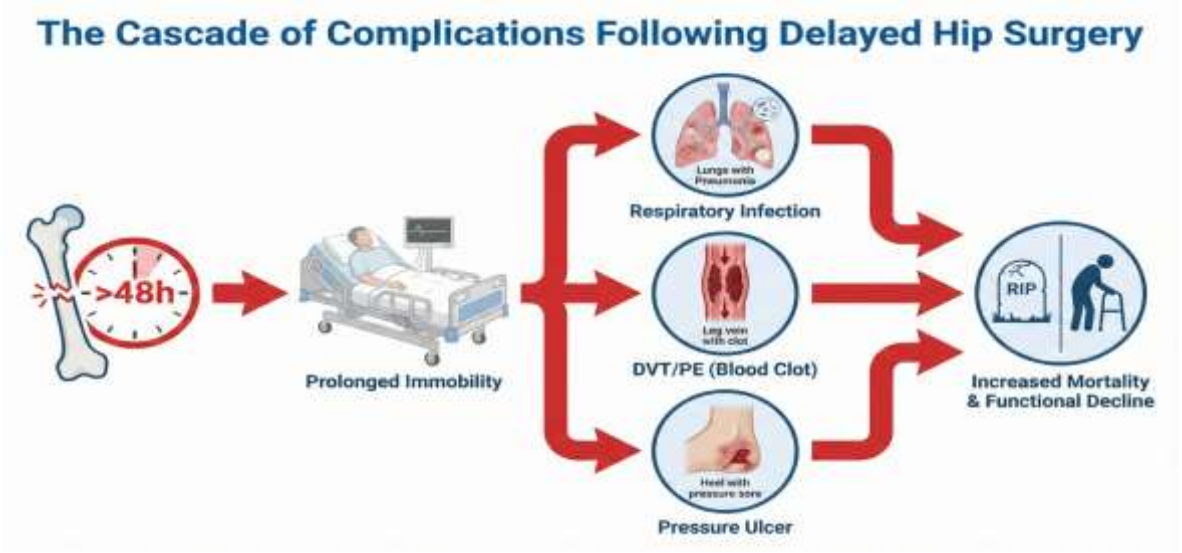
health status. Beyond common systemic complications lie orthopedic-specific sequelae whose incidence can vary subtly with timing profiles. For instance, mechanical fixation failures such as implant cut-out may be more frequent when early surgery occurs under suboptimal reduction due to emergency scheduling constraints (Tosun et al., 2023). Though rarer than systemic infections or DVTs, these events prolong recovery and expose patients to secondary procedures that carry their own risk amplifications, reinforcing why speed benefits must remain matched with execution quality. Nutritional status interlaces meaningfully with complication susceptibility irrespective of timing category. Underweight patients exhibit increased wound healing problems and susceptibility to infection after fracture repair (Yang et al., 2022), while obesity, though associated with heightened prosthesis-related complication risks generally, has shown unexpectedly lower long-term mortality post-surgery relative to average weight peers. These nutritional extremes alter baseline probabilities enough that marginal gains from fast intervention may be overshadowed without simultaneous nutritional support measures during hospitalization. In synthesizing these strands under PRISMA-compliant methodology, the weight of evidence supports operative timing within 48 hours as beneficial for reducing a core cluster of postoperative complications most strongly tied to prolonged preoperative bedrest: pneumonia, urinary tract infections, pressure ulcers, and thromboembolic events. Yet this relationship operates within an interplay network involving patient readiness for anesthesia, institutional throughput efficiency especially under seasonal load variation (Joosten, 2024), concurrent rehabilitation access post-fixation (Agarwal et al., 2024), and modifiable perioperative factors such as anticoagulant management policies influencing anesthesia choices (Sundet et al., 2024). When any component falters, as seen during pandemic-induced system slowdowns, the protective effect linked purely to surgical speed dilutes rapidly. Consequently, interpreting complication data alongside mortality patterns requires an integrated view wherein faster operation is valuable but remains conditional on broader care continuum capabilities ensuring stability at induction and mobility soon after closure.

4.3 Functional recovery

Functional recovery after femoral neck fracture surgery reflects a complex interplay between operative timing, patient physiology, and postoperative rehabilitation processes. Prevention of immobilization-related complications is a foundation for improved recovery trajectories, yet ultimate restoration of independence depends equally on the quality and timing of mobility re-initiation once fixation or arthroplasty has been performed. Early surgical intervention, generally defined within a 48-hour window, offers a distinct advantage by curtailing the period of enforced inactivity, thereby reducing muscle atrophy and preserving neuromuscular coordination essential for resuming ambulation (Lin et al., 2023). Patients who undergo timely operations more frequently achieve pre-fracture walking ability by discharge, which is itself predictive of lower one-year mortality (Morri et al., 2019). Empirical observations demonstrate that short-term declines in activities of daily living (ADL) scores during the first three postoperative months can serve as indicators for long-term outcomes. Individuals showing minimal deterioration in this early phase tend to have superior scores on ADL and quality-of-life assessments, such as the EuroQol EQ-5D-3L, at one year. This connection underscores that surgical timeliness not only impacts immediate mobility but seeds sustained benefits over an extended recovery arc. Physiologically resilient patients, those with intact muscle strength and lower comorbidity burden, appear especially likely to capitalize on these early functional gains. In contrast, those with pronounced frailty or high Charlson Comorbidity Index (CCI) scores often face slower recovery even when operative timing is optimal; high CCI values have been flagged as predictors of poorer one-year functional outcomes after hip fracture surgery (Yang et al., 2023). Postoperative rehabilitation emerges as perhaps the most critical mediator of these effects. Structured leg-muscle strength training programs spanning several months post-discharge have been shown to increase gait speed, walking distance, and independence in instrumental ADLs among community-dwelling older adults recovering from hip fractures. These findings correspond with prediction models where rehabilitation intensity ranks highest among functional outcome determinants. Variables such as marital status exert indirect influences here, married patients with supportive spouses may maintain greater participation in exercise regimens and social interaction compared to widowed or single counterparts less exposed to encouragement or physical assistance in everyday contexts. Home-based physical therapy protocols further extend hospital-initiated mobility work into domestic settings. Studies highlight improvements in patient satisfaction alongside tangible gains in leg strength and endurance measures like the 6-minute walk

distance when exercises are consistently performed at home (Lin et al., 2023). Such interventions appear to harness the momentum provided by swift operative repair, maximising functional potential by preventing regression after discharge. Conversely, if rehabilitation access or adherence falters, as can happen due to staffing shortages or logistical barriers, early surgery's benefits risk erosion despite initially favourable intra-hospital progress. Cognitive status also shapes the slope of recovery curves. Diminished cognitive function impairs capacity to engage effectively with physiotherapy routines; dementia patients undergoing hip fracture repair often exhibit high mortality rates and reduced functional rebound compared to cognitively intact peers (Bai et al., 2018). For these groups, establishing multidisciplinary treatment frameworks that integrate tailored exercise plans with proactive medical management can help mitigate some deficits postoperatively. From an operational standpoint, delays born from systemic constraints, seasonal admission peaks or bottlenecks caused by concurrent epidemics, pose threats to timely mobilization even after early surgery, since therapy initiation may be postponed once theatre schedules compress against rehabilitation staffing limits (Joosten, 2024).

Figure 2: The physiological cascade following delayed surgery for hip fracture.



This dynamic reinforces that functional recovery is not purely a product of surgical timing but also hinges on uninterrupted continuity into the rehabilitation phase. Preoperative ASA physical status classification aligns indirectly with postoperative functional profiles: higher ASA grades signal greater systemic disease burden that correlates with constrained activity resumption within weeks following fracture repair (Li-Huan et al., 2017). The relationship implies that patients in poorer health may require modified expectations regarding rapid full-function restoration even if their surgeries occur within optimal timeframes. Synthesis from multiple high-quality studies shows that early intervention primes patients for better outcomes, but realization of such potential depends critically on subsequent engagement with structured exercise regimens both inpatient and home-based (Lin et al., 2023), close monitoring during vulnerable early months to prevent excessive ADL decline (Yang et al., 2023), and integration of social support mechanisms capable of sustaining activity through the entire convalescence period. Where all these elements coexist, a stable physiological foundation at surgery time, immediate mobilization supported by skilled rehabilitation teams, robust outpatient therapy adherence, the probability of returning to pre-fracture mobility levels one year later increases substantially. However, any break in this chain, from delayed physiotherapy starts due to resource strain to under-treatment of comorbidities impacting stamina, has potential to attenuate or nullify gains achieved via timely surgery.

5 Ethical considerations

5.1 Patient autonomy and informed consent

Respecting a patient's autonomy in the context of femoral neck fracture surgery demands that information about treatment options, potential benefits, and associated risks is communicated in a manner that is both comprehensive and comprehensible to the individual or their legally designated representative. This process influences not only the ethical legitimacy of proceeding with early (within

48 hours) versus delayed surgical intervention but also intersects with measurable outcomes such as mortality rates, postoperative complication frequencies, and functional recovery trajectories. The obligation to secure informed consent involves more than securing a signature; it is an interactive exchange where preferences, values, and health priorities are factored into the clinical plan (Bui et al., 2024). For elderly patients, particularly those above 75 years with higher frailty scores or cognitive impairments, the practical execution of this exchange may require involvement of relatives or caregivers who can help interpret information while safeguarding the patient's own wishes. In acute fracture scenarios, time constraints imposed by evidence supporting expedited surgery create tension between acting swiftly to reduce mortality risk and allowing enough deliberation to achieve truly informed choices. Observational data indicate that surgical repair within 48 hours often confers survival advantages for physiologically stable patients (De Luca, 2023), but exceptions arise when comorbidity stabilization justifies deferment despite general population-level trends. Communicating this nuance is essential: informing patients or surrogates that while early surgery statistically reduces risks like pneumonia, venous thromboembolism, and pressure ulcer development (Klestil et al., 2018), there are scenarios where immediate intervention may raise intraoperative hazard profiles due to uncontrolled medical conditions. The shared decision-making model offers a practical framework here, integrating both evidence-based recommendations and personal value systems into operative planning. Literature suggests that particularly for frail elders or those with limited life expectancy, non-surgical management might preserve quality-of-life metrics without measurably shortening survival (Bui et al., 2024). Presenting such data supports ethically sound refusal rights while maintaining respect for clinical realities. Explicit discussion of treatment alternatives, including conservative approaches, ensures the patient's right to self-determination is upheld even under time-sensitive circumstances. Cognitive impairment introduces a major ethical complexity. In cases where the patient lacks decision-making capacity due to advanced dementia or acute delirium at admission, legal proxies provide consent based on substituted judgment or best-interest principles (Huette et al., 2020). The acute care team must document all discussions thoroughly, particularly where proxies opt against early intervention despite known statistical advantages. This not only protects legal standing but preserves transparency in how ethical trade-offs between expedience and perceived benefit were navigated. There is also an economic dimension influencing consent realism. Surgical options differ in resource utilization, prosthesis costs, anesthesia requirements, post-ICU demands, which can affect acceptance when out-of-pocket expenses are pertinent (D. Zhang et al., 2023). Disclosing these elements respects autonomy by revealing factors beyond physiological outcomes that could influence an individual's choice. While clinical teams may view operational timeliness solely through a survival lens, some patients prioritize minimizing hospitalization length or avoiding post-discharge institutionalization over incremental mortality reductions. The challenge intensifies under systemic pressures such as seasonal case-load surges or pandemic-related restrictions that impede immediate access to theatre slots (Joosten, 2024). Where organisational delay appears unavoidable, clinicians must still engage in honest dialogue about anticipated impacts on complication profiles and recovery potential. This mitigates later perceptions of coercion or misrepresentation should outcomes diverge from initial expectations. Providing numerical ranges, e.g., expected one-year mortality differentials from registry data, can anchor these conversations in transparent probabilistic terms rather than vague assurances. Early preoperative interventions like carbohydrate loading have shown potential benefits in specific orthopedic populations by reducing postoperative morbidity (Zhu et al., 2023), yet they require coordinated implementation before anesthesia induction. Here again, informed consent should encompass not just whether surgery proceeds early or late but also what ancillary measures will accompany the chosen path to optimize recovery odds. Anesthesia modality selection exemplifies another domain where patient preference intersects with outcome probability. While spinal anesthesia may be preferred locally for hip fracture repair (Sundet et al., 2024), institutional policies on drug discontinuation (e.g., DOAC washout) might necessitate delays that alter risk-benefit balances linked explicitly to operative timing. Patients apprised of these policy-derived constraints can voice preferences, for example, electing timely surgery under general anesthesia rather than waiting two days for neuraxial eligibility, thus retaining agency over trade-offs intrinsic to their care. Consent discussions also extend into postoperative expectations: functional recovery likelihoods vary according to baseline mobility and comorbidity burden (Yang et al., 2023). By clarifying how quickly rehabilitation will commence post-surgery, and noting that outcomes deteriorate if mobilization stalls even after technically prompt fixation (Agarwal et al., 2024),

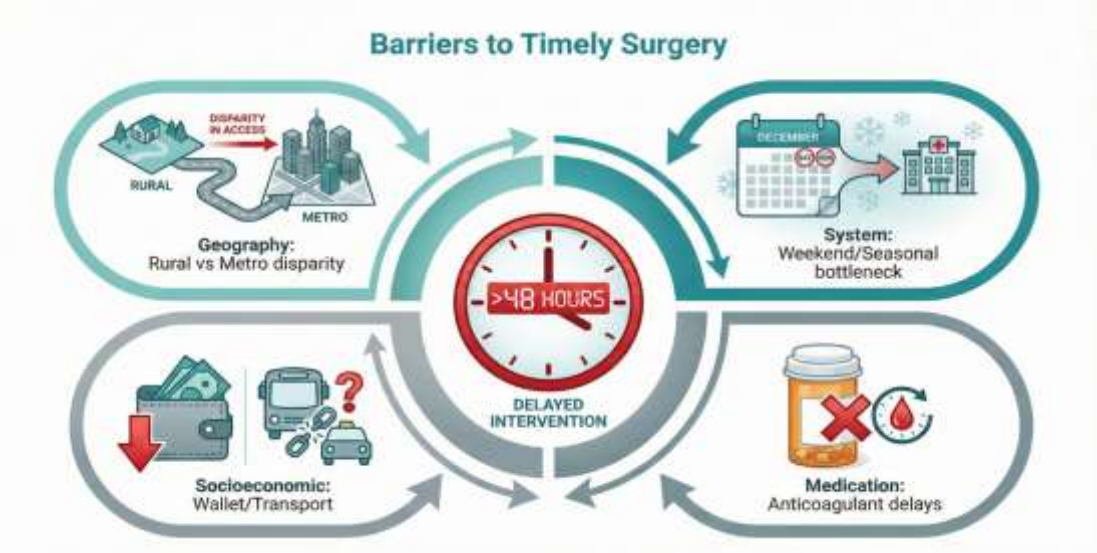
patients can make timing decisions aligned with their tolerance for potential dependency periods. Ultimately, upholding informed consent in this context requires continuous reassessment; a patient consenting upon admission might alter their decision if deterioration occurs during preoperative optimization phases. Documented iterative communication throughout this window respects evolving perspectives while preserving compliance with professional guidelines advocating shared decision-making grounded in current evidence synthesis (Bui et al., 2024). The balance sought is delicate: securing prompt surgery to maximize empirical outcome benefits without sacrificing the deliberative process essential for honoring autonomous choice, even when immediate action carries measurable statistical advantage in mortality reduction and long-term functional independence maintenance.

5.2 Equity of access to timely surgery

Equity of access to timely operative intervention for femoral neck fractures is shaped by a matrix of patient-level factors, institutional capacity, and broader systemic determinants. Variations in surgical timing often originate not purely from medical necessity but from disparities in healthcare resource distribution, procedural prioritization policies, and socioeconomic contexts that influence how quickly a patient reaches the operating theatre after admission. These differences have tangible downstream effects on mortality rates, complication profiles, and long-term functional recovery. Observational data repeatedly indicate that performing surgery within 48 hours reduces short-term mortality (De Luca, 2023), yet such benefit accrues primarily in settings able to offer consistent operative access regardless of admission surges or patient demographics. Geographic variability in orthopaedic service provision remains one of the most visible inequities. Hospitals in metropolitan areas with onsite trauma teams and high-volume theatres are more likely to admit hip fracture patients directly and operate within recommended windows compared to rural or smaller centers. Transfers between institutions, often necessary when initial presentation occurs at facilities without orthopaedic coverage, can add hours to days before surgery, compounding delays already associated with administrative triage (Joosten, 2024). Evidence shows that prolonged time-to-surgery from transfer correlates with increased length of hospital stay (LOHS) and higher exposure to immobilization-related complications such as urinary tract infections and pressure ulcers (Morri et al., 2019). Seasonal peaks in fracture incidence exacerbate these constraints; during springtime surges or icy winter periods linked to more falls, orthopaedic theatre availability can become saturated, inadvertently creating timing discrepancies across patient cohorts (Yonai et al., 2024). Institutional protocols also exert unequal effects. For example, adherence to interventional guidelines on discontinuation intervals for direct oral anticoagulants before neuraxial anaesthesia can vary widely. Some centers follow conservative 48–72 hour waits (Sundet et al., 2024), while others take a case-by-case approach that allows earlier surgery under general anaesthesia if systemic risks are deemed low. Strict adherence to longer washout protocols, without provision for alternative anaesthetic strategies, tends to shift anticoagulated patients into later categories despite otherwise being fit for early intervention. This introduces an equity issue when identical fracture presentations receive disparate timing based on facility policy rather than patient physiology. The COVID-19 pandemic accentuated pre-existing inequities by diverting operating room resources toward urgent respiratory cases and reducing elective surgical throughput through infection control measures. Infected patients with hip fractures faced not only higher mortality risk due to viral pathology but also frequent deferrals of surgery because of ICU bed scarcity or staffing shortages from quarantined personnel (Wang et al., 2023). The combined impact was amplified in regions with already stretched trauma cover; patients were differentially affected based on which hospital they reached at presentation. Socioeconomic status further mediates equitable access. Lower-income individuals may be more likely to present later after injury due to transport or healthcare-seeking barriers, narrowing the available window before physiologic decline begins. They also may have higher baseline comorbidity burdens, chronic cardiac or pulmonary disease, that push them into optimisation pathways extending time-to-surgery beyond ideal thresholds (Lin et al., 2023). While medical preparedness justifies some delay, such patterns are indirectly rooted in social determinants of health that stratify populations into groups systematically less likely to access the benefits of prompt repair. Equity considerations extend beyond getting onto the operating table rapidly; timely access to postoperative rehabilitation is equally inconsistent across different systems and demographic strata. Even if early surgery is achieved, lack of physiotherapy staffing, often in smaller hospitals or during peak seasons, can postpone mobilisation commencement (Agarwal et al., 2024). Without day-0 or day-1 ambulation support, expected reductions

in pneumonia or DVT incidence attributed to early surgery diminish markedly. This disparity manifests particularly in facilities where rehabilitation resources are not scaled proportionally with seasonal rises in fracture admissions. The complexity increases when examining high-risk subgroups such as octogenarians with high Clinical Frailty Scale scores or those residing in long-term care facilities. Studies show these groups already face longer hospitalisation due partly to care planning hurdles (e.g., aligning post-discharge institutional placement), which can influence surgeon willingness to expedite procedures if immediate return to pre-fracture living conditions seems unlikely (Mohseni et al., 2024). While individually rationalised for resource allocation efficiency, these decisions collectively result in population-level differences whereby frailer patients undergo delayed operations more often, not always because they would not benefit from expedited fixation but because system incentives align weakly with their rehabilitation prospects. Differential guideline adherence compounds inequities. Despite national directives advocating early intervention within 48 hours as a quality-of-care metric (De Luca, 2023), audits reveal inconsistent compliance across trauma centers. In some regions, only a minority meet benchmarks due to overnight admission bottlenecks or weekend staffing models that deprioritize hip fracture repair outside standard weekday schedules. This operational lag creates clusters of delayed surgeries tied more strongly to hospital practice models than clinical indication urgency. Addressing these inequities requires both systemic reform and micro-level process adaptation. On a macro scale, expanding orthopaedic coverage networks and streamlining cross-hospital transfer agreements can reduce geography-derived variability. Ensuring small-volume hospitals have rapid protocolised pathways for engaging tertiary centres helps minimise added delay from interfacility movement. On-site solutions include implementing shared theatre lists spanning specialties during high-volume seasons so that urgent fragility fracture cases do not languish behind elective caseloads, a model already tested successfully in some UK major trauma centers facing limb reconstruction backlog pressures (Joosten, 2024). At the patient level, embedding frailty assessment early in emergency department pathways could flag those who stand to lose most from delay so they receive scheduling priority irrespective of chronological age alone (Mohseni et al., 2024). Similarly, institutions can review anticoagulation management protocols for flexibility where safe alternatives exist, for example selective use of general anaesthesia rather than enforcing uniform neuraxial eligibility wait times, to avoid unjustified exclusion from earlier slots (Sundet et al., 2024). Without correcting such structural imbalances, any statistical survival advantage derived from early femoral neck fracture surgery will remain unevenly distributed across populations, and those systematically disadvantaged will continue experiencing disproportionate rates of pneumonia, thromboembolism, functional dependency at one year (Morri et al., 2019), and ultimately mortality rates above what optimally timed care could achieve. The ethical challenge lies not solely in acknowledging that early intervention saves lives but ensuring that logistical realities permit all eligible patients equal opportunity to access it regardless of geography, socioeconomic position, comorbid profile, or admission seasonality.

Figure 3: Systemic barriers to equitable surgical timing.



6 Conclusion

Surgical timing in the management of femoral neck fractures emerges as a critical factor influencing mortality, postoperative complications, and functional recovery, particularly within elderly populations. Evidence consistently indicates that intervention within 48 hours of injury correlates with improved survival rates, reduced incidence of immobilization-related adverse events such as pneumonia, deep vein thrombosis, urinary tract infections, and pressure ulcers, as well as enhanced restoration of pre-fracture mobility and independence. These benefits appear most pronounced in patients who are physiologically stable and able to undergo anesthesia without extensive preoperative optimization. Conversely, individuals with severe comorbidities or high frailty scores may require medical stabilization prior to surgery, where premature operative efforts could increase intraoperative risks and negate potential advantages of expedited repair.

The interplay between surgical timing and patient-specific factors such as inflammatory status, nutritional reserves, cognitive function, and comorbidity burden shapes outcome trajectories, suggesting that timing alone does not dictate prognosis. Postoperative rehabilitation timing and intensity further modulate recovery, with early mobilization serving as a necessary complement to prompt surgery to achieve meaningful functional gains. Institutional and systemic variables, including seasonal admission surges, resource availability, anesthesia protocols, and anticoagulation management policies, also influence the feasibility and effectiveness of early intervention. These factors contribute to observed heterogeneity in outcomes and highlight disparities in access to timely surgical care.

Ethical considerations emphasize the importance of informed consent processes that balance the urgency of early surgery with respect for patient autonomy, especially in frail or cognitively impaired individuals. Equitable access remains a challenge, as geographic, socioeconomic, and institutional disparities can delay operative treatment and rehabilitation, disproportionately affecting vulnerable groups. Addressing these inequities requires coordinated efforts to optimize healthcare delivery pathways, prioritize high-risk patients based on frailty assessments, and adapt perioperative protocols to minimize unnecessary postponements.

Overall, integrating surgical timing within a comprehensive care framework that accounts for individual patient readiness, institutional capacity, and postoperative rehabilitation resources offers the best prospect for improving survival and functional outcomes after femoral neck fractures. Future strategies should focus on refining triage algorithms, enhancing perioperative optimization, and ensuring continuity of care to maximize the benefits associated with early surgical intervention while safeguarding patient safety and autonomy.

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