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Preoperative Lower Respiratory Tract Infection and Postoperative Mortality in Elderly Hip Fracture Patients: A Retrospective Cohort Study

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Abstract

Background

Preoperative lower respiratory tract infection (LRTI) is common in elderly hip fracture patients, but its prognostic significance remains understudied. We aimed to investigate whether preoperative LRTI is independently associated with postoperative mortality in this population.

Methods

This retrospective cohort study included 1,922 elderly patients (≥ 60 years) who underwent hip fracture surgery at a single Level I trauma center between 2015 and 2021. Preoperative LRTI was identified from medical records according to European guidelines. The primary outcomes were 30-day and 1-year all-cause mortality. Hierarchical Cox regression models (Models 1–5) were used to sequentially adjust for demographics, nutritional and inflammatory status, comorbidities, surgical factors, and postoperative complications. Subgroup analyses were performed.

Results

Preoperative LRTI was present in 319 patients (16.6%). In fully adjusted models, preoperative LRTI was independently associated with increased 30-day mortality (HR 2.68, 95% CI 1.67–4.33) and 1-year mortality (HR 1.71, 95% CI 1.30–2.26). Patients with preoperative LRTI also had significantly higher rates of postoperative cardiac events (8.8% vs. 2.9%) and new-onset pneumonia (21.6% vs. 6.8%). In exploratory subgroup analyses the association appeared stronger in patients with low neutrophil-to-lymphocyte ratio (NLR), although this finding requires validation in future studies.

Conclusions

Preoperative LRTI is an independent risk factor for both short- and medium-term mortality in elderly hip fracture patients. Preoperative LRTI should be actively screened for and incorporated into preoperative risk stratification. Future multicenter prospective studies are needed to validate these findings and determine whether preoperative optimization can improve outcomes.

Introduction

Hip fractures in older adults have emerged as a critical global public health challenge. With the accelerating aging of the world population, the annual incidence of geriatric hip fractures is projected to continue rising through 2050[1]. Early surgical intervention is the cornerstone of treatment to preserve functional independence; however, postoperative mortality has not declined substantially over the past

two decades[2, 3], underscoring the urgent need to identify modifiable risk factors to improve patient outcomes.

Extensive research has established postoperative pneumonia as one of the primary risk factors for both short- and long-term mortality in this population, underscoring the critical importance of in-hospital infection control. However, the academic focus has largely been confined to the prevention and management of postoperative complications. In contrast, there is a striking paucity of systematic investigation into whether pre-existing infections at the time of admission—particularly lower respiratory tract infection (LRTI)—might influence postoperative prognosis. This knowledge gap may result in incomplete clinical risk assessment and the missed opportunity for crucial preoperative optimization.

Older adults with hip fractures represent a uniquely vulnerable population. They frequently present with multimorbidity [4] and frailty, a state of diminished physiological reserve[5, 6]. Both multimorbidity and frailty are intrinsically linked to immune dysfunction and chronic low-grade inflammation[7–9]. Critically, these systemic vulnerabilities not only increase the risk of falls and fractures [10] but also predispose patients to infections such as LRTI, which in turn adversely affect prognosis[4, 8, 10, 11]. For instance, the INSPIRE cohort study demonstrated that frailty not only increases the risk of acute LRTI but is also exacerbated by the infection itself[12]. Similarly, another retrospective study found that anemia significantly increased readmission and mortality in octogenarians with LRTI[13]. Therefore, we hypothesize that a pre-existing LRTI at the time of hospitalization may serve as a sentinel marker of the patient's underlying systemic vulnerability. This infection may exacerbate the postoperative systemic inflammatory response and increase the risk of secondary complications, thereby posing a significant threat to long-term survival.

Based on this background, we designed a retrospective cohort study to evaluate whether preoperative LRTI is an independent risk factor for postoperative 30-day and 1-year mortality in elderly hip fracture patients, after rigorous adjustment for a comprehensive panel of confounders. By identifying preoperative LRTI as a potentially modifiable risk factor, our findings may provide novel evidence to inform risk stratification and guide individualized perioperative decision-making, including more intensive preoperative anti-infective therapy, respiratory optimization, and early multidisciplinary team involvement in high-risk patients, with the ultimate goal of improving outcomes in this vulnerable population.

Methods

Human Ethics, consent to participate declarations, data source and study design

This single-center retrospective study was approved by the Ethics Committee of The Seventh Medical Center, Chinese PLA General Hospital (No. 2015-081), with the approval covering the entire study period (2015–2021). The study was conducted in accordance with the Declaration of Helsinki. Given the retrospective use of deidentified data extracted from routine clinical care, with no direct patient contact

or experimental interventions, the requirement for informed consent for the retrospective data analysis was waived by the Ethics Committee. For the telephone-based follow-up conducted for outcome ascertainment, written informed consent to participate declaration was obtained from each patient or their legal guardian prior to the follow-up interview. Clinical trial number: not applicable.

Between January 2015 and December 2021, patients with hip fractures who underwent surgery in the orthopedic department of the Seventh Medical Center, Chinese PLA General Hospital, were included in this retrospective analysis. The case data were derived from our hip fracture patient database, which was established more than a decade ago[14, 15]. The inclusion criteria were as follows: (1) ≥ 60 years of age, (2) fragility hip fracture (defined as low-energy trauma caused by falling to the ground), (3) isolated hip fracture that was not associated with other fractures requiring surgical treatment. The exclusion criteria were as follows: (1) patients with pathological fractures, (2) patients with high-energy injuries, (3) patients with multiple fractures, (4) patients with periprosthetic fractures or with contralateral hip fracture happened.

Diagnosis, evaluation, and therapies for preoperative lower respiratory tract infection (LRTI)

All patients received a chest X-ray or chest CT upon admission. In this retrospective study, the diagnosis of preoperative lower respiratory tract infection (LRTI) was directly extracted from patients' medical records. Only those cases with a clear, documented diagnosis of LRTI recorded before hip fracture surgery were considered as having preoperative LRTI. The diagnoses were required to correspond to the disease categories defined by the European Guidelines for the Management of Adult Lower Respiratory Tract Infections [16], including community-acquired pneumonia (CAP), acute exacerbation of chronic obstructive pulmonary disease (AECOPD), acute bronchitis and acute exacerbation of bronchiectasis.

For each included patient, two independent investigators reviewed the medical records to confirm that the documented LRTI diagnosis was explicitly stated by the attending physicians prior to surgery. Any disagreement between the two investigators regarding the presence or type of LRTI was resolved by discussion with a third senior clinician. Cases with ambiguous, suspected, or undocumented LRTI (e.g., only symptoms or radiographic findings without a final recorded diagnosis) were excluded from the LRTI group, unless otherwise specified in a separate analysis.

Management of confirmed preoperative LRTI was delivered under a multidisciplinary orthogeriatric co-management model, involving orthopedic surgeons, geriatricians, and respiratory physicians. Treatment comprised anti-infective therapy (empirical or pathogen-directed antibiotics according to the European guidelines [14]) and supportive respiratory care, including oxygen supplementation, airway clearance techniques (postural drainage, assisted coughing), and nebulized bronchodilator therapy when clinically indicated. All therapeutic decisions were made by the attending physicians based on individual patient assessment and clinical severity, consistent with the principle that clinically fit patients should proceed to surgery as soon as possible while unstable patients receive preoperative optimization. The details of

antibiotic regimens, duration of therapy, and specific supportive measures were documented in the medical records but were not included as covariates in the primary analyses, given the retrospective design of this study.

Surgery

Current clinical guidelines for the management of hip fractures in older adults strongly recommend early surgical intervention, ideally within 24 to 48 hours of admission, as delayed surgery is associated with increased morbidity and mortality. In our cohort, those with documented severe hypoxemia supported by mechanical ventilation, sepsis or septic shock secondary to LRTI were considered to have a relative contraindication to immediate surgery, and the decision to delay or proceed with surgery was determined by the attending physicians on a case-by-case basis in accordance with these guidelines.

In general, patients with surgical indications undergo one of four types of surgical management according to the fracture pattern, including three cannulated cancellous screws for nondisplaced femoral neck fractures, bipolar cemented or cementless hemiarthroplasty or total hip arthroplasty for displaced femoral neck fractures, dynamic hip screws (DHSs) for stable intertrochanteric fractures, and cephalomedullary nails for unstable intertrochanteric and subtrochanteric fractures. Regarding anesthetic management, patients received either general anesthesia or regional anesthesia (including neuraxial anesthesia and peripheral nerve blocks), based on the anesthesiologist ’s assessment and the patient’s overall condition. Routine follow-up was performed during patient visits to the clinic or via phone interviews by a special team consisting of two orthopedic surgeons and four nurses at 30 days, 6 months, and 1 year post-operatively and every year thereafter.

Outcomes

The primary outcomes of this study were all-cause mortality within 30 days and within 1 year after surgery, as post-operative 30-day mortality is often used to reflect the acute complications that occur during surgery and in the early postoperative period, whereas 1-year mortality is associated with postoperative functional recovery, comorbidity management, and long-term health status. Postoperative complications during hospitalization including delirium, new-onset postoperative pneumonia, cardiac events (myocardial infarction, new arrhythmia requiring intervention, or acute heart failure), gastrointestinal bleeding, and cerebrovascular events (ischemic stroke or intracranial hemorrhage) were all recorded. All patients were followed up until death or at least one year after discharge.

Covariates and hierarchical adjustment strategy

To rigorously evaluate the independent association between preoperative LRTIs and postoperative mortality, and to assess the stability of this association across progressively more conservative adjustment sets, we adopted a hierarchical (stepwise) adjustment strategy. This approach served two

primary purposes: (1) to quantify the extent to which the observed association was explained by different domains of confounders; and (2) to determine whether preoperative LRTI retained its prognostic significance even after accounting for the most comprehensive set of available confounders.

The following covariates were selected based on clinical plausibility and our previous literature [21–23] [14], and were sequentially entered into five Cox regression models: Model 1 adjusted for age (< 80 vs. ≥ 80 years), sex (male or female), and fracture type (femoral neck vs. trochanteric) to account for basic demographic and injury-related differences; Model 2 further adjusted for nutritional and inflammatory status, including prognostic nutritional index (PNI; low < 45 vs. normal ≥ 45), body mass index (BMI; low < 22 vs. normal ≥ 22 kg/m^2), neutrophil-to-lymphocyte ratio (NLR; low < 7 vs. high ≥ 7), preoperative anemia (no or yes), and preoperative lower extremity venous thrombosis (no or yes), to capture the patient's baseline physiological reserve; Model 3 additionally adjusted for a comprehensive set of pre-existing comorbidities (hypertension, coronary artery disease, arrhythmia, ischemic or hemorrhagic stroke, chronic obstructive pulmonary disease, chronic kidney disease, diabetes, and chronic cardiac insufficiency; no or yes) to control for multimorbidity burden; Model 4 further adjusted for surgical and perioperative factors, including time from admission to surgery (≤ 48 h vs. > 48), surgical procedure type (fixation vs. arthroplasty), anesthesia type (general vs. regional), American Society of Anesthesiologists (ASA) grade (I–II vs. III–IV), and volume of packed red blood cell transfusion (< 4 U vs. ≥ 4 U), to account for variations in surgical management; Model 5 additionally adjusted for postoperative complications as a composite binary variable (present vs. absent), defined as the occurrence of any of the following events during the index hospitalization: postoperative delirium, new-onset postoperative pneumonia, cardiac events, gastrointestinal bleeding, and cerebrovascular events. Patients who experienced at least one of these complications were classified as having postoperative complications, regardless of the type or number of events. This adjustment was performed as a sensitivity analysis to assess whether the effect of preoperative LRTI on mortality was independent of these downstream events, or whether it was substantially mediated through in-hospital complications.

Subgroup Analyses

To explore whether the association between preoperative LRTI and mortality varied across clinically relevant patient strata, we performed predefined subgroup analyses based on the following baseline characteristics: age, presence of COPD, diabetes mellitus, BMI, PNI, NLR, sex, and anesthesia type. Based on previous literature demonstrating its optimal predictive performance for short-term mortality in elderly hip fracture patients[17], an NLR cutoff of **7** was used for the primary subgroup analyses to stratify patients into low (< 7) and high (≥ 7) NLR groups.

For each subgroup, we re-estimated the adjusted HR for preoperative LRTI using the fully adjusted Model 4 (excluding postoperative complications) to preserve the total effect, as adjusting for postoperative complications would constitute over-adjustment. Strata with fewer than 10 events were not adjusted due to model instability; only descriptive data for these strata are presented in Supplementary Table S1 and

Table S2. For strata with ≥ 10 events, adjusted HRs and interaction P-values are reported in the main table.

Statistical Analysis

Baseline characteristics were compared between patients with and without preoperative LRTI using descriptive techniques. Continuous variables with a normal distribution were presented as mean ± standard deviation (SD) and compared using independent-samples t-tests; non-normally distributed variables were expressed as median with interquartile range (IQR) and compared using the Mann–Whitney U test. Categorical variables were presented as frequencies and percentages and compared using the χ^2 test or Fisher's exact test, as appropriate.

To evaluate the association between preoperative LRTI and postoperative mortality, we performed multivariable Cox proportional hazards regression to estimate hazard ratios (HRs) with 95% confidence intervals (CIs) for 30-day and 1-year all-cause mortality. The proportional hazards assumption was verified using Schoenfeld residual tests. The five hierarchical models described above (Models 1–5) were fitted to assess the robustness of the association. Additionally, Kaplan–Meier survival curves with log-rank tests were constructed to visualize the survival differences between the LRTI and non-LRTI groups.

All statistical analyses were performed using SPSS software (version 23.0; IBM Corp., Armonk, NY, USA). A two-sided $P < 0.05$ was considered statistically significant for all primary analyses, except for interaction tests where $P < 0.10$ was used as the threshold for significance.

Results

Patient characteristics and Postoperative Complications

Between January 2015 and December 2021, we performed 2180 surgical procedures for elderly patients with hip fractures. Among those patients, 1922 met the inclusion criteria and comprised the final study cohort. The median patient age was 82 (75, 86) years, and 1307 (68.0%) were female. Preoperative LRTIs was found in 319 patients (16.6% of 1922 patients). A flowchart of the study design and the prevalence of preoperative LRTIs are shown in Fig. 1. Patients with preoperative LRTI were significantly older, had poorer nutritional status (lower PNI, higher prevalence of anemia), and exhibited higher baseline inflammatory levels (elevated NLR) compared with those without LRTI. They also had a higher burden of comorbidities, particularly coronary artery disease, arrhythmias, cardiac insufficiency, dementia, and COPD. Regarding perioperative variables, the LRTI group had a lower proportion of delayed surgery (> 48 hours) and a higher proportion of ASA grade III–IV (Table 1).

Table 1
Characteristics of patients with or without preoperative lower respiratory tract infection (LRTI)

Variables	**Without LRTI (n = 1603)**	**With LRTI (n = 319)**	***P-value***
Age (years), median (IQR)	81 (75, 86)	84 (80, 89)	< 0.001
Age ≥ 80 years	911 (56.8)	246 (77.1)	< 0.001
Female sex, (n, %)	1090 (68.0)	217 (68.0)	0.992
Type of fracture, (n, %)			0.732
Trochanteric fracture	913 (57.0)	185 (58.0)	
Femoral neck fracture	690 (43.0)	134 (42.0)	
PNI < 45	1012 (63.1)	238 (74.6)	< 0.001
BMI(< 22 kg/m²)	588 (36.7)	121 (37.9)	0.673
Preoperative anemia	715 (44.6)	169 (53.0)	0.006
NLR, median (IQR)	5.3 (3.7, 7.5)	6.1 (4.1, 8.9)	< 0.001
NLR > 7, (n, %)	468 (29.2)	133 (41.7)	< 0.001
Comorbidities, (n, %)			
Hypertension	942 (58.8)	191 (60.1)	0.667
Coronary artery disease	396 (24.7)	100 (31.3)	0.013
Arrhythmias	187 (11.7)	77 (24.2)	< 0.001
Cardiac insufficiency	94 (5.9)	35 (11.0)	< 0.001
Stroke	472 (29.4)	108 (33.9)	0.117
Dementia	121 (7.6)	36 (11.3)	0.029
Renal insufficiency	86 (5.4)	23 (7.2)	0.193
Diabetes	463 (28.9)	75 (23.5)	0.050
COPD	117 (7.3)	58 (18.2)	< 0.001
Malignancy	53 (3.3)	8 (2.5)	0.458
Parkinson's disease	17 (1.1)	5 (1.6)	0.437
From injury to surgery > 48 hours, (n, %)	682 (42.5)	98 (30.7)	< 0.001

Variables	Without LRTI (n = 1603)	With LRTI (n = 319)	*P-value*
Type of anesthesia, (n, %)			0.748
Reginal anesthesia	1106 (69.0)	223(69.9)	
General anesthesia	497 (31.0)	96 (30.1)	
Type of surgery, (n, %)			0.729
Fixation	1115 (69.6)	225 (70.5)	
Arthroplasty	488 (30.4)	94(29.5)	
ASA grade			< 0.001
□-□	805 (50.2)	118 (37.0)	
□-□	798 (49.8)	201 (63.0)	
Transfusion on the day of surgery ≥ 4 U, (n, %)	424 (26.5)	88 (27.6)	0.675
Length of hospitalization (days), median (IQR)	12 (9, 15)	12 (9,16)	0.101

As shown in Table 2, postoperative complications were significantly more common in patients with preoperative LRTI than in those without (36.0% vs. 17.8%, P < 0.001). Specifically, patients with preoperative LRTI had significantly higher rates of cardiac events (8.8% vs. 2.9%, P < 0.001) and new-onset postoperative pneumonia (21.6% vs. 6.8%, P < 0.001). No significant differences were observed in delirium, gastrointestinal bleeding, or cerebrovascular events between the two groups (all P > 0.05).

Table 2
Distribution and number of postoperative complications with or without preoperative lower respiratory tract infection (LRTI)

Variables	Without LRTI (n = 1603)	With LRTI (n = 319)	*P-value*
Participants, (n, %)	286 (17.8)	115 (36.0)	< 0.001
Cardiac events, (n, %)	47 (2.9)	28 (8.8)	< 0.001
New-onset postoperative pneumonia, (n, %)	109 (6.8)	69 (21.6)	< 0.001
Delirium, (n, %)	127 (7.9)	31 (9.2)	0.286
Gastrointestinal bleeding, (n, %)	30 (1.9)	6 (1.9)	0.991
Cerebrovascular events, (n, %)	19 (1.2)	8 (2.5)	0.067

Associations between preoperative LRTIs and postoperative mortality

During the 30-day postoperative period, 34 (10.7%) deaths occurred in the preoperative LRTI group, compared with 48 (3.0%) in the non-LRTI group. In the unadjusted Cox regression analysis, preoperative LRTI was associated with a significantly increased risk of 30-day mortality (crude HR 3.66, 95% CI 2.36–5.68, P = 0.001). The association between preoperative LRTI and 30-day mortality remained significant across all hierarchical models, with a fully adjusted HR of 2.68 (95% CI 1.67–4.33, P < 0.001) in Model 4. In the sensitivity analysis further adjusting for postoperative complications (Model 5), the HR was attenuated but remained significant (2.39, 95% CI 1.47–3.87, P < 0.001) (Table 3).

Table 3
Associations between preoperative lower respiratory tract infection (LRTI) and postoperative 30-day mortality

Participants (n)	**Without LRTI**	**With LRTI**	***P* value**
	1603	**319**	**—**
Events (n)	48	34	—
Crude HR (95% CI)	Reference	3.66 (2.36–5.68)	0.001
Adjusted HR (95% CI)			
Model 1	Reference	3.10 (1.99–4.83)	*P* < 0.001
Model 2	Reference	2.90 (1.85–4.54)	*P* < 0.001
Model 3	Reference	2.59 (1.62–4.14)	*P* < 0.001
Model 4	Reference	2.68 (1.67–4.33)	*P* < 0.001
Model 5	Reference	2.39 (1.47–3.87)	*P* < 0.001

Model 1: adjusted for age, sex, and fracture type; Model 2: further adjusted for PNI, BMI, NRL, preoperative anemia, preoperative lower extremity venous thrombosis; Model 3: adjusted for hypertension, coronary artery disease, arrhythmia, ischemic or hemorrhagic stroke, chronic obstructive pulmonary disease, chronic kidney disease, diabetes, chronic cardiac insufficiency, Model 4, adjusted for time to surgery, surgical procedure type, anesthesia type, transfusion volume and covariates in Model 1. Model 5, further adjust for postoperative complications. The results are presented as Hazard ratios (HRs) with 95% confidence intervals (CIs).

During the 1-year follow-up period, 80 (25.1%) deaths occurred in the preoperative LRTI group, compared with 201 (12.5%) in the non-LRTI group. In the unadjusted analysis, preoperative LRTI was significantly associated with increased 1-year mortality (crude HR 2.18, 95% CI 1.68–2.83, P = 0.001). The Kaplan-Meier survival curves showed a progressive decline in 1-year survival with increasing severity of preoperative hyponatremia (log-rank test for trend, P < 0.001) (Fig. 2). After sequential adjustment, the HR was 1.71 (95% CI 1.30–2.26, P < 0.001) in the fully adjusted Model 4, and remained significant (1.61, 95% CI 1.22–2.13, P < 0.001) in Model 5 for sensitivity analysis (Table 4).

Table 4
Associations between preoperative lower respiratory tract infection (LRTI) and postoperative 1-year mortality

Participants (n)	Without LRTI	With LRTI	*P* value
	1603	**319**	**—**
Events (n)	201	80	—
Crude HR (95% CI)	Reference	2.18 (1.68–2.83)	0.001
Adjusted HR (95% CI)			
Model 1	Reference	1.95 (1.50–2.54)	*P* < 0.001
Model 2	Reference	1.74 (1.33–2.27)	*P* < 0.001
Model 3	Reference	1.65 (1.26–2.16)	*P* < 0.001
Model 4	Reference	1.71 (1.30–2.26)	*P* < 0.001
Model 4	Reference	1.61 (1.22–2.13)	*P* < 0.001

Model 1: adjusted for age, sex, and fracture type; Model 2: further adjusted for PNI, BMI, NRL, preoperative anemia, preoperative lower extremity venous thrombosis; Model 3: adjusted for hypertension, coronary artery disease, arrhythmia, ischemic or hemorrhagic stroke, chronic obstructive pulmonary disease, chronic kidney disease, diabetes, chronic cardiac insufficiency, Model 4, adjusted for time to surgery, surgical procedure type, anesthesia type, transfusion volume and covariates in Model 1. Model 5, further adjust for postoperative complications. The results are presented as Hazard ratios (HRs) with 95% confidence intervals (CIs).

Subgroup Analyses

As shown in Table 5, subgroup analyses were performed to explore whether the association between preoperative LRTI and mortality varied across patient characteristics. Given the exploratory nature of these analyses, findings should be interpreted with caution.

Across nearly all subgroups, preoperative LRTI was consistently associated with increased 30-day and 1-year mortality. For 30-day mortality, significant associations were observed in patients aged ≥ 80 years (HR 2.40, 95% CI 1.42–4.06), those without COPD (HR 2.83, 95% CI 1.70–4.71), those without diabetes (HR 2.98, 95% CI 1.68–5.28), patients with BMI ≥ 22 kg/m² (HR 3.40, 95% CI 1.69–6.83), those with PNI < 45 (HR 2.63, 95% CI 1.53–4.50), and those receiving regional anesthesia (HR 2.86, 95% CI 1.63–5.02). For 1-year mortality, significant associations were observed in both age strata, both BMI strata, both PNI strata, both sexes, and both anesthesia types (all P < 0.05).

Among the variables examined, only a few showed potential effect modifications. Age showed a borderline interaction for 30-day mortality (P = 0.064), with a significant association confined to patients aged ≥ 80 years. NLR showed a significant interaction for 30-day mortality (P < 0.001), with a stronger

association in patients with low NLR (HR 5.35, 95% CI 2.82–10.13) than in those with high NLR (HR 1.22, 95% CI 0.55–2.72); however, this finding was exploratory and not statistically significant for 1-year mortality (P = 0.237). Diabetes showed a borderline interaction for 1-year mortality (P = 0.078), with a stronger association in diabetic patients (HR 2.88, 95% CI 1.74–5.93) than in non-diabetic patients (HR 1.53, 95% CI 1.09–2.14). No significant effect modification was observed for other variables (all P for interaction > 0.10).

Table 5
Subgroup analyses for the association between preoperative LRTIs and 30-day and 1-year mortality

Subgroup	30-day mortality			1-year mortality		
	Adjusted HR (95%CI)	P	P for Interaction	Adjusted HR (95%CI)	P	P for Interaction
Age			0.063			0.122
< 80 years	Not performed	—		2.85 (1.57–5.17)	< 0.001	
≥ 80 years	2.40 (1.42–4.06)	0.001		1.57 (1.16–2.14)	0.004	
NRL (cutoff 7)			< 0.001			0.237
< 7	5.35 (2.82–10.13)	< 0.001		2.23 (1.55–3.21)	< 0.001	
≥ 7	1.22 (0.55–2.72)	0.623		1.30 (0.85–1.98)	0.231	
COPD			0.687			0.581
No	2.83 (1.70–4.71)	< 0.001		1.86 (1.38–2.50)	< 0.001	
Yes	Not performed	—		1.92 (0.80–4.60)	0.144	
Diabetes			0.334			0.078
No	2.98 (1.68–5.28)	< 0.001		1.53 (1.09–2.14)	0.013	
Yes	Not performed	—		2.88 (1.74–5.93)	< 0.001	
BMI			0.514			0.834
≥ 22	3.40 (1.69–6.83)	< 0.001		1.76 (1.20–2.59)	< 0.001	
< 22	2.59 (1.32–5.09)	0.006		1.83 (1.21–2.75)	0.004	
PNI			0.753			0.159
≥ 45	Not performed	—		2.14 (1.05–4.37)	0.036	

Notes: Strata with fewer than 10 outcome events were not subjected to multivariable adjustment owing to model instability; only descriptive data (events/total) are presented for these subgroups in Supplementary Table S1and S2.

Subgroup	30-day mortality			1-year mortality		
	Adjusted HR (95%CI)	P	P for Interaction	Adjusted HR (95%CI)	P	P for Interaction
< 45	2.63 (1.53–4.50)	< 0.001		1.67 (1.23–2.26)	< 0.001	
Sex			0.286			0.164
Female	2.05 (1.14–3.71)	0.017		1.56 (1.09–2.24)	0.015	
Male	Not performed	—		2.23 (1.44–3.45)	< 0.001	
Anesthetic method			0.806			0.327
general	Not performed	—		2.20 (1.33–3.65)	0.002	
regional	2.86 (1.63–5.02)	< 0.001		1.67 (1.19–2.33)	0.003	

Notes: Strata with fewer than 10 outcome events were not subjected to multivariable adjustment owing to model instability; only descriptive data (events/total) are presented for these subgroups in Supplementary Table S1and S2.

Discussion

In this retrospective cohort study of 1,922 elderly patients undergoing hip fracture surgery, preoperative LRTI was present in 16.6% of patients and was independently associated with a significantly increased risk of both 30-day (adjusted HR 2.68, 95% CI 1.67–4.33) and 1-year (adjusted HR 1.71, 95% CI 1.30–2.26) postoperative mortality. In exploratory subgroup analyses, the association appeared stronger in patients with low baseline NLR, but this observation remains hypothesis-generating and requires validation in independent cohorts.

Preoperative LRTI: vulnerability, complications, and mechanistic pathways

In this cohort, patients with preoperative LRTI were significantly older, had poorer nutritional status (lower PNI, higher anemia prevalence), a higher burden of comorbidities, and more advanced ASA grades. These findings align with previous evidence linking hypoalbuminemia and poorer functional status to increased infection risk [19] [20]. Collectively, these observations suggest that preoperative LRTI may serve as a sentinel marker of the patient's overall physiological vulnerability—a confluence of aging, malnutrition, comorbidity, and functional decline—rather than an isolated infectious event. This systemic vulnerability predisposes patients to both the development of preoperative infection and its

postoperative consequences. Indeed, patients with preoperative LRTI had significantly higher rates of cardiac events (8.8% vs. 2.9%) and new-onset postoperative pneumonia (21.6% vs. 6.8%), both well-established drivers of postoperative mortality, suggests that preoperative LRTI not only identifies a vulnerable host but also actively contributes to a cascade of adverse events underlying the excess mortality[21, 22].

The mechanisms underlying the association between preoperative LRTI and postoperative mortality likely differ by time frame. In the early postoperative period (within 30 days), the two-hit phenomenon—preoperative infection compounded by surgical stress and anesthesia—may overwhelm the patient's physiological reserve and precipitate multiorgan dysfunction or acute respiratory failure[23]. This is consistent with the substantially stronger effect observed at 30 days (HR 2.68) than at 1 year (HR 1.71). This mechanism also aligns with our subgroup findings that the short-term lethal effect of LRTI was pronounced in patients with lower physiological reserve (PNI < 45: HR 2.63) and older age (≥ 80 years: HR 2.40), both of which may render patients more vulnerable to early mortality.

In the medium term (beyond 30 days up to 1 year), a protracted inflammatory and catabolic state may accelerate preexisting comorbidities, exacerbate malnutrition, and lead to progressive functional decline [24]. This is supported by our subgroup finding that diabetes showed a potential effect modification at 1 year (P for interaction = 0.078), with a substantially higher HR in diabetic patients (HR 2.88, 95% CI 1.74–5.93) than in non-diabetic patients (HR 1.53, 95% CI 1.09–2.14).

In exploratory subgroup analyses, the association between preoperative LRTI and 30-day mortality appeared stronger in patients with low baseline NLR. This observation, while hypothesis-generating, is consistent with the concept that patients with limited inflammatory reserve may be more vulnerable to the combined insult of infection and surgery. However, given the exploratory nature of this analysis and the single-center design, this finding requires validation in future multicenter studies and should not be over-interpreted.

In summary, acute inflammatory and respiratory insults appeared to dominate early mortality, while sustained metabolic and functional consequences may have contributed to the excess mortality at 1 year. These observations suggest that the mechanisms linking preoperative LRTI to postoperative mortality may be time-dependent, and further investigation is warranted to clarify the underlying pathways.

Clinical implications

Our findings have several important clinical implications. First, preoperative LRTI should be actively screened for at admission in all geriatric hip fracture patients. Given that elderly patients often present with atypical symptoms—such as confusion, falls, or failure to thrive rather than classic fever or productive cough—a high index of suspicion and routine chest imaging may be warranted [20]. This is particularly important because our data showed that preoperative LRTI was present in 16.6% of patients, a proportion substantially higher than previously reported in some series, suggesting that it may be

under-recognized in routine practice. Second, the presence of LRTI should be incorporated into preoperative risk stratification. Our finding that preoperative LRTI was independently associated with a 2.7-fold increase in 30-day mortality and a 1.7-fold increase in 1-year mortality—after adjustment for a comprehensive panel of confounders—supports the inclusion of LRTI status as a routine component of preoperative assessment in this population. Third, the differential effects between 30-day and 1-year mortality suggest that the greatest threat lies in the immediate postoperative period. This temporal pattern has direct implications for the intensity and duration of postoperative monitoring: patients with preoperative LRTI may benefit from more frequent respiratory and hemodynamic assessments, early mobilization, and a lower threshold for intensive care unit admission during the first postoperative week. Fourth, our findings highlight the need for a multidisciplinary approach. Given the high burden of comorbidities in this population and the association between LRTI and postoperative complications—including cardiac events and new-onset pneumonia—close collaboration among orthopedic surgeons, geriatricians, respiratory physicians, and anesthesiologists is essential for optimizing perioperative management. Finally, the substantial mortality risk associated with preoperative LRTI, even after rigorous adjustment, raises the question of whether surgery should be delayed for infection control in selected patients. While current guidelines recommend early surgery, our findings suggest that in patients with clinically significant LRTI, individualized decision-making—balancing the risks of surgical delay against the risks of operating during an active infection—may be warranted. Future prospective studies are needed to determine the optimal timing of surgery in this high-risk subgroup.

Strengths and Limitations

This study has several strengths. First, to our knowledge, this is the first study to systematically explore effect modification of the preoperative LRTI-mortality association using a hierarchical adjustment strategy and comprehensive subgroup analyses. Second, the large sample size (1,922 patients) and sufficient outcome events enabled robust multivariable modeling. Third, we employed a stepwise adjustment strategy (Models 1–5) to sequentially account for different domains of confounders and assess the stability of the effect estimate. Fourth, we distinguished between 30-day and 1-year mortality, allowing for time-specific risk assessment.

Several limitations should be acknowledged. First, this was a single-center retrospective study, subject to selection bias and residual confounding. Although we adjusted for a wide range of covariates, unmeasured confounders such as LRTI severity, antibiotic regimens, and timing of therapy initiation may have influenced the outcomes. Second, the diagnosis of preoperative LRTI relied on medical record review rather than prospective standardized assessment, which may have introduced information bias. However, we applied clear diagnostic criteria and involved independent reviewers to adjudicate ambiguous cases. Third, subgroup analyses were exploratory and not adjusted for multiple comparisons; therefore, these findings should be considered hypothesis-generating; in some subgroups with fewer than 10 events, multivariable adjustment was not feasible, limiting statistical power. Fourth, detailed data on antibiotic regimens and LRTI severity were not available, which may have introduced residual

confounding. Fifth, the generalizability of our findings to other populations or healthcare settings remains to be determined.

Conclusion

In this retrospective cohort study of elderly patients undergoing hip fracture surgery, preoperative LRTI was independently associated with increased 30-day and 1-year postoperative mortality after rigorous adjustment for a comprehensive panel of confounders. In exploratory analyses, the association appeared stronger in patients with low baseline NLR, though this finding requires validation in multicenter studies. Clinically, these findings suggest that preoperative LRTI should be actively screened for and incorporated into preoperative risk stratification in this vulnerable population. Future multicenter prospective studies are needed to validate these findings and to further explore the mechanisms linking preoperative infection to adverse postoperative outcomes.

Declarations

Ethical approval and consent to participate

This single-center retrospective study was approved by the Ethics Committee of The Seventh Medical Center, Chinese PLA General Hospital (No. 2015-081), with the approval covering the entire study period (2015–2021). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent to participate declaration was obtained from each patient or their legal guardian.

Competing interests

The authors declare no competing interests in this work.

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Author Contribution

Chu LY and Chen XB wrote the manuscript and created tables and figures. Liu WW and Zhang SH performed the statistics. Wang XW and Liu Z performed the data extractions. Xi CH supervised the whole process and revised the manuscript. All authors read the final version.

Data Availability

The data used to support the findings of this study are available from Chunhua Xi upon request.

Abbreviations

LRTI lower respiratory tract infection

NLR neutrophil-to-lymphocyte ratio

HR hazard ratio

CI confidence interval

CAP community-acquired pneumonia

AECOPD acute exacerbation of chronic obstructive pulmonary disease

PNI prognostic nutritional index

BMI body mass index

ASA American Society of Anesthesiologists

COPD chronic obstructive pulmonary disease

PLA People's Liberation Army of China;

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Figures

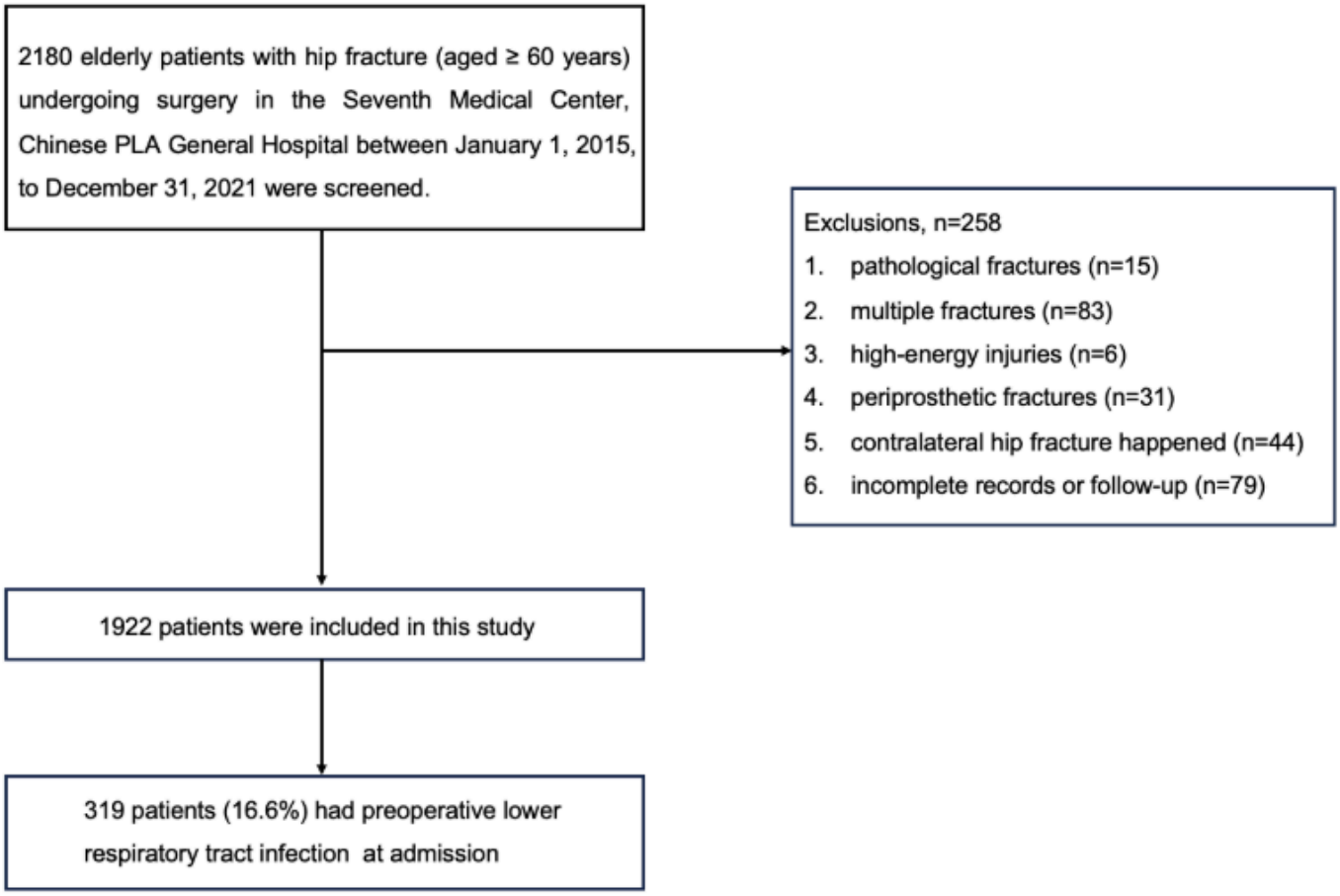


Figure 1

Flowchart of the study design and prevalence of preoperative lower respiratory tract infection (LRTI)

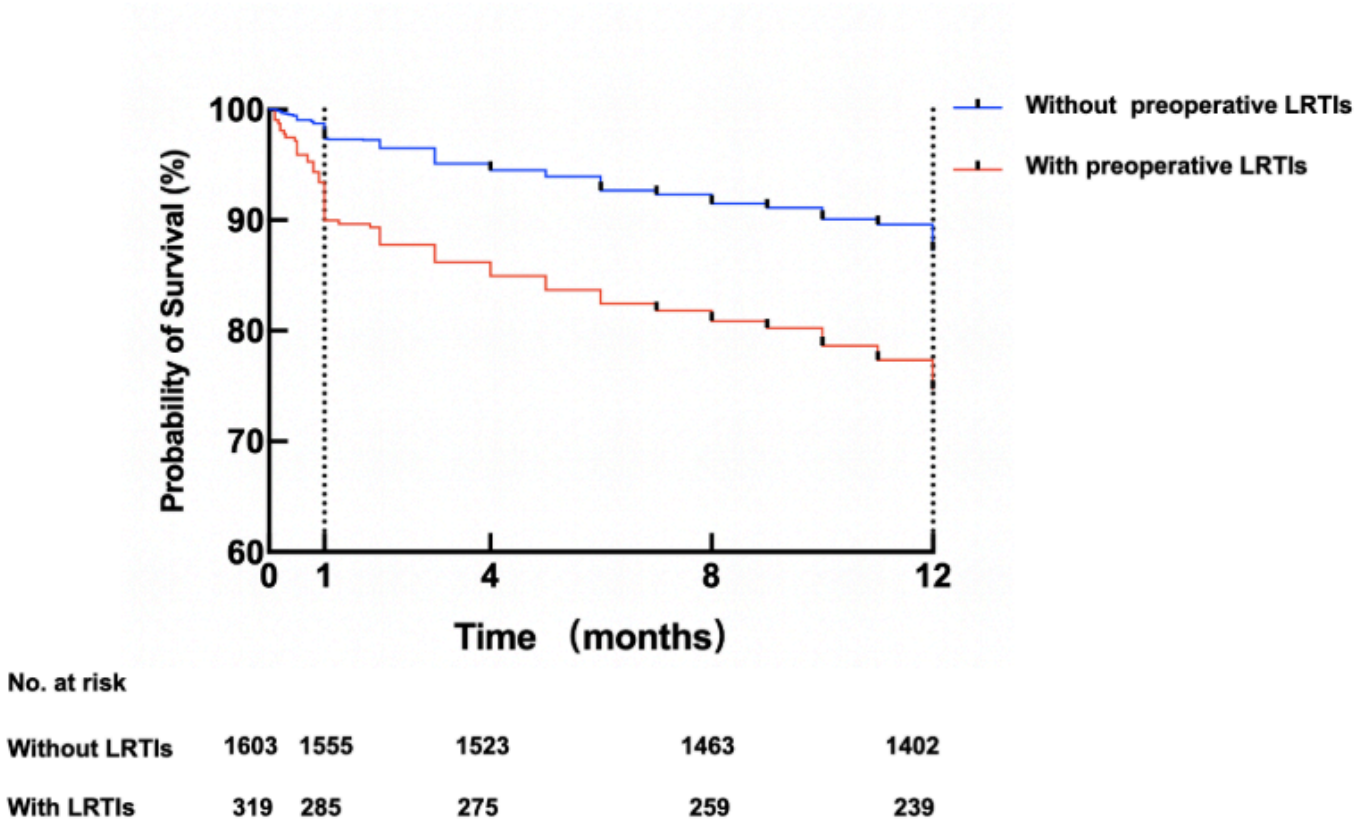


Figure 2

The Kaplan-Meier survival curves showed a progressive decline in 1-year survival with increasing severity of preoperative lower respiratory tract infection (log-rank test for trend, $P < 0.001$)

Supplementary Files

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- 0822TableS1andTableS2.docx