Research Square

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# Association between different surgical procedures and postoperative delirium in geriatric hip fracture patients:a retrospective cohort study

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## Abstract

# Background

It is still not clear whether there are differences in the occurrence of postoperative delirium(POD) among different surgical procedures in elderly people with hip fractures. This research aimed to investigate the impact of different surgical procedures on POD in elderly people with hip fractures.

# Methods

This retrospective cohort study examined the medical records of patients aged 65 and over who underwent hip fracture surgery at a tertiary medical facility from January 2022 to December 2025. Divided patients into groups according to the surgical procedures they received; those who had intramedullary nailing were put into the internal fixation group, and those who had hip hemiarthroplasty or total hip arthroplasty were put into the arthroplasty group. Utilized multivariate logistic regression and propensity score matching (PSM) analysis to evaluate the relationship between different surgical procedures and POD. Then, subgroup analysis was conducted to further probe the possible connections between different surgical procedures and POD.

# Results

A total of 693 patients took part in this study, and there was a 15.01% (104/693) incidence rate of POD during the postoperative hospitalization period. Multivariate logistic regression analysis indicated that the different surgical procedures' POD incidence rate has a statistically significant(OR: 2.64, 95% CI: 1.61–4.32, P < 0.001), and the internal fixation group was higher than the arthroplasty group. All covariates among the groups were well-balanced after PSM, and the PSM analysis didn't change this statistically significant result, and once again confirmed a strong connection between different surgical procedures and POD.

# Conclusions

Different surgical procedures are associated with the risk of POD in elderly people with hip fractures. Internal fixation is associated with a higher risk of POD compared with arthroplasty.

## Introduction

Hip fractures are a leading cause of death and incapacity in elderly patients, and surgical intervention is essential for reestablishing limb functionality and cutting down on long-term mortality[1]. Postoperative delirium(POD) is one of the most severe complications after hip fracture surgery. Recent relevant research has shown the incidence rate ranges from 5% to 20%[2–5]. It stems from the combination of predisposing and precipitating factors; surgery-related factors, such as surgical trauma, pain control, and stress states, are the crucial precipitating factors[6]. At present, internal fixation (femoral intramedullary nailing) and arthroplasty (hip hemiarthroplasty and total hip arthroplasty) are the two chief surgical procedures for geriatric hip fracture patients. The choice of surgical procedure generally relies on the fracture type, patient's age, physical condition, and patient's functional requirements[7]. However, the evidence about the connection between the two surgical procedures and POD is still controversial[8,9]. These earlier studies didn't have strict control over confounding variables and were unable to get rid of potential biases, which might explain the contradictory results. Therefore, this study aims to investigate the impact of different surgical procedures(internal fixation and arthroplasty) on POD in elderly people with hip fractures and provide high-quality evidence-based evidence for clinical practice.

## Methods

# Study design

This study utilized a retrospective cohort design, and eligible participants included patients aged 65 years and over who underwent hip fracture surgery at the Sixth People's Hospital of Huizhou between January 1, 2022, and December 31, 2025. All research processes strictly adhered to the ethical principles outlined in the 1964 Declaration of Helsinki. This study was reviewed and authorized by the Institutional Review Board (IRB) of the aforementioned hospital, with the approval number: KYYJ2026-LY006.

## Patient selection

The inclusion criteria were as follows: 1) patients aged 65 and over who were diagnosed with fragile hip fractures; 2) patients who had undergone surgery for hip fractures, including femoral intramedullary nailing, hip hemiarthroplasty, or total hip arthroplasty. The exclusion criteria were as follows: 1) having multiple injuries or multiple fractures; 2) transfer to the intensive care unit treatment after the operation; 3) incomplete electronic medical records; 4) having a history of neurological or mental disorders except for dementia.

## Data collection

Two authors (BTY and ZXW) carried out the data collection work independently, and meticulously examined and settled any differences so as to guarantee the precision and dependability of the collected data. They drew out demographic details and perioperative period clinical data from the electronic medical record information management system. Another two authors (QT and YTY) did duplicate examinations of the collected data to further confirm the integrity and accuracy of the data.

## Exposure

All patients accepted vital signs monitoring and affected limb skin traction upon admission to the hospital. Routine laboratory examinations and imaging studies were carried out within 48 hours to confirm the fracture type, evaluate surgical indications, and rule out any potential surgical contraindications. According to the clinical practice guidelines, surgical procedure choice depended on the fracture type. Patients with intertrochanteric or subtrochanteric fractures were select internal fixation surgery, while patients with femoral neck fractures were select arthroplasty. After the operation, patients who got internal fixation were told to begin early non-weight-bearing activities, and those who had arthroplasty were encouraged to walk as soon as possible.

## Outcome

The main outcome was POD occurring from the first postoperative day to the day of discharge. The diagnosis of POD was based on the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM – 5), and the Confusion Assessment Method (CAM) was used as the standard diagnostic tool for detecting POD. The CAM consists of four key diagnostic criteria: (1) acute onset of symptoms with a fluctuating clinical course, (2) presence of inattention, (3) disorganized thinking patterns, and (4) altered level of consciousness. For a confirmed diagnosis of POD, patients were required to satisfy both criterion 1 and criterion 2, in addition to meeting either criterion 3 or criterion 4. The assessors(JY and YL) for delirium assessment were fully trained by a psychiatrist.

# Covariables

Based on the risk elements mentioned in the extant relevant research, we gathered covariates from patients' medical files and sorted them into four main groups: demographic variables, comorbidity variables, surgery-related variables, and preoperative laboratory examination variables. Comorbidity variables comprised dementia, diabetes mellitus, cardiovascular diseases, cerebrovascular diseases, chronic pulmonary diseases, disseminated tumors, and renal insufficiency. Surgery-related variables involved surgery duration, intraoperative blood loss, blood transfusion status, American Society of Anesthesiologists (ASA) classification, and anesthesia method. Preoperative laboratory examination variables included leukocyte count, platelet count, hemoglobin level, serum creatinine level, and serum albumin level.

# Statistical analysis

Statistical analyses were performed using SPSS 27.0 and Prism 10.1.2. The Shapiro–Wilk test was used to assess the normality of data distributions. Abnormally distributed continuous data were compared using the Mann–Whitney test and expressed as the median and interquartile range. Categorical data were compared using the chi-square test or Fisher's exact test and expressed as numbers and percentages. Multiple logistic regression analysis was applied to calculate adjusted odds ratios (OR) and 95% confidence intervals (CI). Covariates that showed statistical significance in the univariate logistic regression analysis were integrated into the subsequent multivariate logistic regression models. PSM was performed using a 1:1 nearest neighbor matching approach to balance the internal fixation group and the arthroplasty group. The standardized mean difference (SMD) ≥ 0.10 was utilized to assess potential imbalances in covariates. Patients were stratified into different subgroups according to the predefined covariates for subgroup analysis. The presence of interactions was evaluated by comparing the differences in OR across the various subgroups. Statistical significance was defined as $p < 0.05$.

## Results

# Participant selection

Between January 1, 2022, and December 31, 2025, a total of 866 patients aged 65 and over who had undergone hip fracture surgery were initially identified by reviewing electronic medical records. Among them were 116 patients with multiple trauma or fractures, 28 patients with intensive care unit treatment, 4 patients with incomplete data, and 25 patients with preexisting neurological and psychiatric disorders. After removing the above patients, 693 patients were eventually included in this study, and the general incidence of POD among these included patients was 15.01%. The average age of total was 82(75,88) years, with 488(70.42%) females and 205(29.58%) males. The average of BMI was 22.5(19.4,27.0), and smoking status was 60(8.66%) .The Length of Hospital Stay was 17(11,20) days, and the time to surgery was 5(3,7) days. Among the 693 eligible patients, 330 cases (47.62%) were treated with internal fixation, while other 363 cases (52.38%) were treated with arthroplasty. The detailed patient selection process is illustrated in Fig. 1. Additionally, further analysis revealed that the incidence of POD was significantly higher($P < 0.001$) in the IF group(20.61%) compared with the AR group(9.92%) (Fig. 2A).

# Propensity score matching analysis

Pre-matching univariate regression analysis showed that there were statistically significant distinctions in the baseline features between the two research groups. Therefore, we constructed a PSM cohort by matching 11 key covariates, including age, sex, BMI, time to surgery, dementia, cerebrovascular disease, surgical duration, blood loss, blood transfusion, ASA classification, and anesthesia method. Then, a 1:1 nearest neighbor matching approach was utilized for PSM, and consequently, 275 patients in the internal fixation group were matched with 275 patients in the arthroplasty group. After that, the baseline features between the two groups were in good balance. The standardized mean differences (SMD) for the majority of variables were under 0.10, meaning that there were no major imbalances in the baseline elements (Table 1). Furthermore, consistent with the before-matching results, the incidence of POD remained higher in the internal fixation group(24.36%) than in the arthroplasty group(10.99%) after PSM ($P < 0.001$)(Fig. 2B).

Table 1
Characteristics of patients after propensity score matching analysis

| Characteristics | total(n = 693) | Before matching | | | After matching | | |
|---|---|---|---|---|---|---|---|
| | | IF (n = 330) | AR (n = 363) | SMD | IF (n = 275) | AR (n = 275) | SMD |
| **Demographic** | | | | | | | |
| Age, year | 82(75,88) | 84(77,89) | 80(73,86) | 43.04% | 83(76,88) | 82(75,87) | 6.83% |
| Sex (female), n (%) | 488(70.42) | 222(67.27) | 266(73.28) | -13.15% | 194(70.55) | 191(69.45) | 2.38% |
| BMI, $kg/m^2$ | 22.5(19.4,27.0) | 22.5(19.5,27.1) | 22.7(19.3,26.8) | 5.36% | 22.49(19.1,27.1) | 22.99(19.4,27.0) | -2.51% |
| Smoking, n (%) | 60(8.66) | 30(9.09) | 30(8.26) | 2.93% | 25(9.09) | 26(9.45) | -1.25% |
| Length of Hospital Stay, day | 17(11,20) | 16(11,20) | 17(11,21) | -3.23% | 17(11,20) | 17(11,20) | 0.87% |
| Time to surgery, day | 5(3,7) | 5(3,7) | 5(3,7) | -1.74% | 5(3,7) | 5(3,7) | -1.74% |
| **Comorbidities** | | | | | | | |
| Dementia, n (%) | 18(2.60) | 7(2.12) | 11(3.03) | -5.73% | 7(2.55) | 7(2.55) | 0.00% |
| Diabetes mellits, n (%) | 163(23.38) | 73(22.12) | 89(24.52) | -5.66% | 67(24.36) | 62(22.55) | 4.28% |
| Cardiovascular diseases, n (%) | 426(61.47) | 201(60.91) | 225(61.98) | -2.20% | 172(62.55) | 167(60.73) | 3.73% |
| Cerebrovascular disease, n (%) | 258(37.23) | 103(31.21) | 155(42.70) | -23.94% | 99(36.00) | 105(38.18) | -4.51% |
| Chronic pulmonary diseases, n (%) | 229(33.04) | 119(36.06) | 110(30.30) | 12.23% | 93(33.82) | 77(28.00) | 12.59% |
| Disseminated tumors, n (%) | 31(4.47) | 16(4.85) | 15(4.13) | 13(4.73) | 14(5.09) | 13(4.73) | 1.68% |
| Renal insufficiency, n (%) | 93(13.42) | 48(14.55) | 45(12.40) | 40(14.55) | 40(14.55) | 34(12.36) | 6.39% |
| **Surgery-related** | | | | | | | |
| Surgery duration, min | 70(57,90) | 75(57,95) | 67(56,85) | 25.52% | 70(55,90) | 70(60,85) | 5.15% |
| Blood loss, ml | 200(100,300) | 200(100,300) | 250(150,350) | -11.72% | 200(100,300) | 250(150,350) | -3.81% |
| Blood transfusion, n (%) | 96(12.41) | 41(12.42) | 45(12.40) | 0.08% | 32(11.64) | 37(13.45) | -5.48% |
| ASA | | | | 12.18% | | | -4.26% |
| I/II, n (%) | 168(24.24) | 71(21.52) | 97(26.72) | | 68(24.73) | 63(22.91) | 0.036 |
| III/V, n (%) | 525(75.76) | 259(78.48) | 266(73.28) | | 207(75.27) | 212(77.09) | |
| Anesthesia method | | | | -4.05% | | | 8.60% |
| General, n (%) | 643(92.78) | 308(93.33) | 335(92.29) | | 22(8.00) | 16(5.82) | |
| Regional, n (%) | 50(7.22) | 22(6.67) | 28(7.71) | | 253(92.00) | 259(94.18) | |

IF: Internal Fixation; AR: Arthroplasty; SMD: Standardized Mean Differences; BMI: Body Mass Index; ASA: American Society of Anesthesiologists

| Characteristics | total(n = 693) | Before matching | | | After matching | | |
|---|---|---|---|---|---|---|---|
| | | IF (n = 330) | AR (n = 363) | SMD | IF (n = 275) | AR (n = 275) | SMD |
| **Demographic** | | | | | | | |
| **Preoperative laboratory examinations** | | | | | | | |
| Leukocyte count | 10.9(8.1,12.0) | 10.9(8.6,12.0) | 10.8(8.0,12.1) | -0.03% | 10.87(8.0,12.0) | 10.85(8.0,12.1) | -1.83% |
| Platelet count | 243(206,281) | 243(207,283) | 244(205,2831) | -1.51% | 244(207,286.0) | 245(209,286) | -2.03% |
| Hemoglobin | 103(97,109) | 103(98,109) | 103(97,109) | 0.27% | 103(98,109) | 104(97,109) | 3.75% |
| Albumin | 36(33,38) | 36(33,38) | 36(33,38) | -3.28% | 36(33,38) | 36(34,38) | -1.52% |
| Creatinine | 90(63,110) | 90(63,110) | 89(63,112) | 3.95% | 92(63,116) | 92(64,112) | -0.17% |

IF: Internal Fixation; AR: Arthroplasty; SMD: Standardized Mean Differences; BMI: Body Mass Index; ASA: American Society of Anesthesiologists

# Multiple logistic regression analysis

Univariate and multivariate logistic regression analyses were performed to explore the associations between various clinical factors and postoperative delirium (POD), with the detailed results presented in Table 2. Univariate logistic regression analysis identified ten variables that were significantly associated with POD ($P < 0.05$). After adjusting for potential confounding factors using multivariate logistic regression analysis, seven variables were confirmed as independent risk factors for POD ($P < 0.05$), specifically: dementia (odds ratio [OR] = 9.61, 95% confidence interval [CI]: 3.28 ~ 28.16), cerebrovascular disease (OR = 2.69, 95%CI: 1.64 ~ 4.40), surgical procedures (OR = 2.64, 95%CI: 1.61 ~ 4.32), renal insufficiency (OR = 1.82, 95%CI: 1.02 ~ 3.24), age (OR = 1.06, 95%CI: 1.03 ~ 1.09), length of hospital stay (OR = 1.02, 95%CI: 1.01 ~ 1.04), and leukocyte count (OR = 0.91, 95%CI: 0.84 ~ 0.98). Notably, cardiovascular disease, chronic pulmonary disease, and ASA classification lost their statistical significance in the multivariate regression model ($P > 0.05$). Additionally, smoking and other variables that were not significant in the univariate analysis remained irrelevant to the occurrence of POD ($P > 0.05$).

Table 2
Univariate and multivariate logistic regression analyses for POD

| Characteristics | Univariate | | Multivariate | |
|---|---|---|---|---|
| | OR 95%CI | *p* | OR 95%CI | *p* |
| **Demographic** | | | | |
| Age, year | 1.07 (1.04 ~ 1.09) | < .001 | 1.06 (1.03 ~ 1.09) | < .001 |
| Sex (female), n (%) | 0.76 (0.49 ~ 1.18) | 0.223 | <NA> | <NA> |
| BMI, kg/cm2 | 1.00 (0.96 ~ 1.04) | 0.939 | <NA> | <NA> |
| Smoking, n (%) | 1.84 (0.97 ~ 3.48) | 0.062 | <NA> | <NA> |
| Length of Hospital Stay, day | 1.02 (1.01 ~ 1.04) | 0.015 | 1.02 (1.01 ~ 1.04) | 0.038 |
| Time to surgery, day | 1.03 (0.99 ~ 1.07) | 0.120 | <NA> | <NA> |
| **Comorbidities** | | | | |
| Dementia, n (%) | 6.11 (2.36 ~ 15.77) | < .001 | 9.61 (3.28 ~ 28.16) | < .001 |
| Diabetes mellits, n (%) | 1.11 (0.68 ~ 1.80) | 0.671 | <NA> | <NA> |
| Cardiovascular diseases, n (%) | 1.96 (1.23 ~ 3.13) | 0.005 | 1.52 (0.91 ~ 2.55) | 0.111 |
| Cerebrovascular disease, n (%) | 2.57 (1.68 ~ 3.93) | < .001 | 2.69 (1.64 ~ 4.40) | < .001 |
| Chronic pulmonary diseases, n (%) | 2.22 (1.46 ~ 3.39) | < .001 | 1.25 (0.77 ~ 2.05) | 0.368 |
| Disseminated tumors, n (%) | 0.60 (0.18 ~ 1.99) | 0.400 | <NA> | <NA> |
| Renal insufficiency, n (%) | 2.97 (1.79 ~ 4.92) | < .001 | 1.82 (1.02 ~ 3.24) | 0.042 |
| **Surgery-related** | | | | |
| Surgery duration, min | 1.00 (1.00 ~ 1.01) | 0.176 | <NA> | <NA> |
| Blood loss, ml | 1.00 (1.00 ~ 1.00) | 0.542 | <NA> | <NA> |
| Blood transfusion, n (%) | 1.23 (0.67 ~ 2.24) | 0.500 | <NA> | <NA> |
| ASA | 2.08 (1.17 ~ 3.71) | 0.013 | 1.15 (0.59 ~ 2.23) | 0.679 |
| Anesthesia method | 1.46 (0.71 ~ 3.02) | 0.307 | <NA> | <NA> |
| Surgical procedures | 2.36 (1.53 ~ 3.64) | < .001 | 2.64 (1.61 ~ 4.32) | < .001 |
| **Preoperative laboratory examinations** | | | | |
| Leukocyte count | 0.92 (0.85 ~ 0.98) | 0.011 | 0.91 (0.84 ~ 0.98) | 0.009 |
| Platelet count | 1.00 (1.00 ~ 1.00) | 0.848 | <NA> | <NA> |
| Hemoglobin | 1.00 (0.98 ~ 1.02) | 0.923 | <NA> | <NA> |
| Creatinine | 1.02 (0.97 ~ 1.07) | 0.426 | <NA> | <NA> |
| Albumin | 1.00 (0.99 ~ 1.00) | 0.246 | <NA> | <NA> |

OR: Odds Ratio; CI: Confidence Interval; BMI: Body Mass Index; ASA: American Society of Anesthesiologists.

# Subgroup analyses

Subgroup analyses were carried out with POD being the dependent variable, different surgical procedures as the exposure elements, and 11 covariates (age, sex, BMI, time to surgery, dementia, cerebrovascular diseases, surgical duration, blood loss, blood transfusion, ASA, and anesthesia method) adjusted for. Stratified subgroup analyses founded on demographic variables, comorbidity variables, surgery-related variables, and preoperative laboratory examination variables showed that the length of hospital stay(interaction P = 0.005), cardiovascular disease(interaction P = 0.046), chronic pulmonary disease(interaction P = 0.017), renal insufficiency(interaction P < 0.01), and serum creatinine levels(interaction P = 0.045) demonstrated substantial interaction impacts on the occurrence of POD among different surgical

procedures. Specifically, patients whose length of hospital stay was over 17 days, serum creatinine levels were more than 90 μmol/L, or who had concomitant cardiovascular disorder, chronic pulmonary disease, or renal insufficiency had a considerably higher incidence of POD in comparison to those without these traits.

## Discussion

POD is a common and serious complication of geriatric hip fracture patients. It is greatly lengthens hospital stays, raises medical expenses, impaires cognitive function, and results in higher mortality rates[10 – 12]. Therefore, identifying risk factors that boost delirium is extremely important for enhancing the prognosis of elderly hip fracture patients. Through a retrospective cohort study, we specifically probed into the connection between different surgical procedures and the incidence of POD in elderly hip fractures, and our results showed that internal fixation surgery has a higher incidence of POD in contrast to arthroplasty.

Up to now, there haven't many large-scale systematic reviews directly compared internal fixation with arthroplasty surgical procedures on the incidence of POD in geriatric hip fracture patients. A small-scale clinical retrospective study supported our conclusions by Liu XH has showed that patients who received internal fixation surgery had a higher POD incidence than those who received arthroplasty[8]. Nevertheless, there was a conflict in the former literature. Surucu S et al compared proximal femoral intramedullary nailing (an internal fixation method) with hemiarthroplasty; they discovered that patients in the intramedullary nailing group suffered from less severe postoperative cognitive impairment[9]. This difference result might be due to the following factors: First, the main outcome in our study was acute POD, which was strongly related to acute perioperative stress, neuroinflammation, and neurotransmitter imbalance[13]. While the latter study focused on chronic postoperative cognitive dysfunction (PCD), pathophysiological mechanisms and clinical presentations different from POD, which was a situation possibly involving irreversible neuronal damage[14]. Second, different evaluation tools were used in the two studies. We adopted the CAM scale, which was especially validated for diagnosing acute delirium, while the latter study used the Mini-Mental State Examination (MMSE) scale, which was more often used for assessing general cognitive function instead of acute delirium. Third, in our study, the arthroplasty group contained both hip hemiarthroplasty and total hip arthroplasty patients, while the comparative study only included hip hemiarthroplasty. It should be noted that Argun G et al. demonstrated there was no difference in postoperative cognitive dysfunction between hip hemiarthroplasty and total hip arthroplasty[15], which might reduce the potential influence of this difference on our results.

Though a great number of earlier studies have discovered the risk factors for POD among elderly hip fracture patients, such as advanced age, preoperative cognitive dysfunction, coexisting medical disorders, and anesthetic choice[16–18]. Research on the impact of different surgical procedures on POD is still scarce. In our study, we observed a relatively higher incidence of POD in the internal fixation group compared with the arthroplasty group. Through our analysis, we believe this difference cannot be attributed to a single factor. Instead, it is a result of the combined effects of stress responses, systemic inflammatory reactions, pain management approaches, and postoperative rehabilitation models as follows.

Surgery-induced stress responses trigger the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system, resulting in an over-release of cortisol and catecholamines that have been amply shown to be strongly linked to the emergence of POD[13]. During the internal fixation procedure, particularly during fracture reduction and nail insertion, medullary fat, blood clots, and inflammatory factors may enter the systemic circulation. This process could potentially cause cerebral microembolism, which was regarded as a crucial possible mechanism for POD[19]. In contrast, arthroplasty surgery removed the fracture site and femoral head, which is the primary source of pain and abnormal stimulation. Even though intraoperative cerebral fat embolism could also happen during arthroplasty, Colonna DM[20] and Fu M[21] considered it often connected with the use of bone cement. Compared with internal fixation surgery, arthroplasty surgery traumatic insult is more definitive and less persistent.

Surgical trauma unavoidably triggers a systemic inflammatory activation in the human body. This response is characterized by a notable elevation in the levels of pro-inflammatory cytokines, including interleukin-1 (IL-1), interleukin-6 (IL-6), and tumor necrosis factor-α (TNF-α) [22]. Inouye SK et al.[23, 24] considered that these pro-inflammatory cytokines could trigger neuroinflammation via some routes, such as vagal conduction and blood-brain barrier disturbance, which was generally considered a central pathophysiological foundation for POD. After internal fixation surgery, the hip fracture healing process had a long-lasting inflammatory repair stage, involving hematoma and callus formation, which is accompanied by constant inflammatory cell invasion and cytokine secretion[25]. This extended inflammatory reaction gave a continuous impetus to systemic inflammation, making patients more susceptible to perioperative injuries and thus raising the POD risk. In contrast, arthroplasty surgery, if no complications occur, such as surgical site infection, the systemic inflammatory response quickly decreases to a low level[26], which might lead to a lower POD occurrence rate.

Wu J[27] and Vaurio LE[28] considered that Pain has a well-recognized crucial risk factor for POD. After internal fixation surgery, patients frequently endured continuous deep pain from the fracture sites, which typically requires high-dose and long-term opioid administration. Opioids are known to be associated with an increased risk of POD due to their central nervous system inhibitory effects and the accumulation of toxic metabolites[12, 29]. However, arthroplasty surgery got rid of fracture-related pain, leaving just superficial incision pain, which could be dealt with more efficiently by non-steroidal anti-inflammatory drugs (NSAIDs) and multi-modal analgesia approaches such as regional nerve block[11, 30, 31]. This disparity in pain might have further led to the lower POD incidence rate in the arthroplasty group.

Early mobilization is widely recognized as one of the most effective non-pharmacological strategies for preventing POD [11, 32]. It can enhance patient orientation, normalize the sleep-wake pattern, and lessen complications associated with immobility. Numerous patients who underwent internal fixation surgery need a strict duration of 6–12 weeks of non-weight-bearing or partial weight-bearing on the affected limb. This extended restriction on activity could aggravate muscular atrophy, cut down proprioceptive input, and lead to disorientation in environmental perception, all of which significantly raise the risk of POD[33]. However, arthroplasty surgery adheres to the Enhanced Recovery After Surgery (ERAS) notion, which allows patients to stand, walk, or perform functional exercises as soon as possible[34]. This early mobilization serves as a powerful protective factor against POD. Thus, early mobilization is considered one of the primary reasons for the difference in POD incidence rate between the two surgical procedures.

# Limitations

This study had several inherent limitations that ought to be recognized. Firstly, being a retrospective cohort study, it was prone to inbuilt selection bias because the surgical allocation wasn't random but depended on clinical elements like fracture type, bone quality, and the patient's age. Secondly, even though multiple potential confounding variables were adjusted for in the multivariate regression analysis, there might still have been unmeasured confounding aspects that could have affected the results. Thirdly, there could have been diversity in surgical procedures and perioperative management approaches among the participants, which couldn't have been entirely controlled during the analysis. Fourthly, the study was carried out at one center only, which might have restricted the generalizability of our findings, so large-scale multi-center studies were required to verify our conclusions. Lastly, we didn't conduct long-term follow-up regarding cognitive function in the participants; thus, future research should concentrate on clarifying how the two surgical procedures differently impacted acute as opposed to chronic cognitive outcomes.

## Conclusions

In conclusion, our study showed that different surgical procedures are associated with the risk of POD in elderly people with hip fractures. Internal fixation is associated with a higher risk of POD compared with arthroplasty. This disparity was probably due to surgery-induced stress responses, systemic inflammatory activation, pain management approaches, and postoperative rehabilitation patterns.

## Abbreviations

SMD Standardized mean difference

PSM Propensity score matching

BMI Body mass index

ASA American Society of Anesthesiologists

POD Postoperative delirium

OR Odds ratio

CI Confidence interval

IRB Institutional Review Board

DSM-5 Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition

CAM Confusion Assessment Method

PCD Postoperative cognitive dysfunction

MMSE Mini-Mental State Examination

HP Ahypothalamic-pituitary-adrenal

IL-1 Interleukin-1

IL-6 Interleukin-6

TNF-α Tumor necrosis factor-α

NSAIDs Non-steroidal anti-inflammatory drugs

ERAS Enhanced Recovery After Surgery

## Declarations

**Ethics approval and Consent to participate**

This study adhered to the principles of the Declaration of Helsinki and the Ethics Committee Board of the Sixth People's Hospital of Huizhou approved this study (protocol number: KYYJ2026 - LY006), also waiving the requirements for informed consent.

**Consent for publication**

Not Applicable.

**Competing interests**

The authors declare no competing interests.

# Funding

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# Author Contribution

Study concept: XYF and CTH were responsible for it; the study was designed by ZXZ, JSY, and YBL; Data acquisition, analysis, or interpretation were carried out by QT, BTY, ZXW, and YTY; statistical analysis was conducted by ZXZ, XYF, and CTH; the manuscript was drafted by ZXZ, JSY, and YBL; and all authors critically revised the manuscript for important intellectual content.

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Not applicable.

# Data Availability

All the data used and analyzed during the current study are available from the corresponding author upon reasonable request.

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## Figures

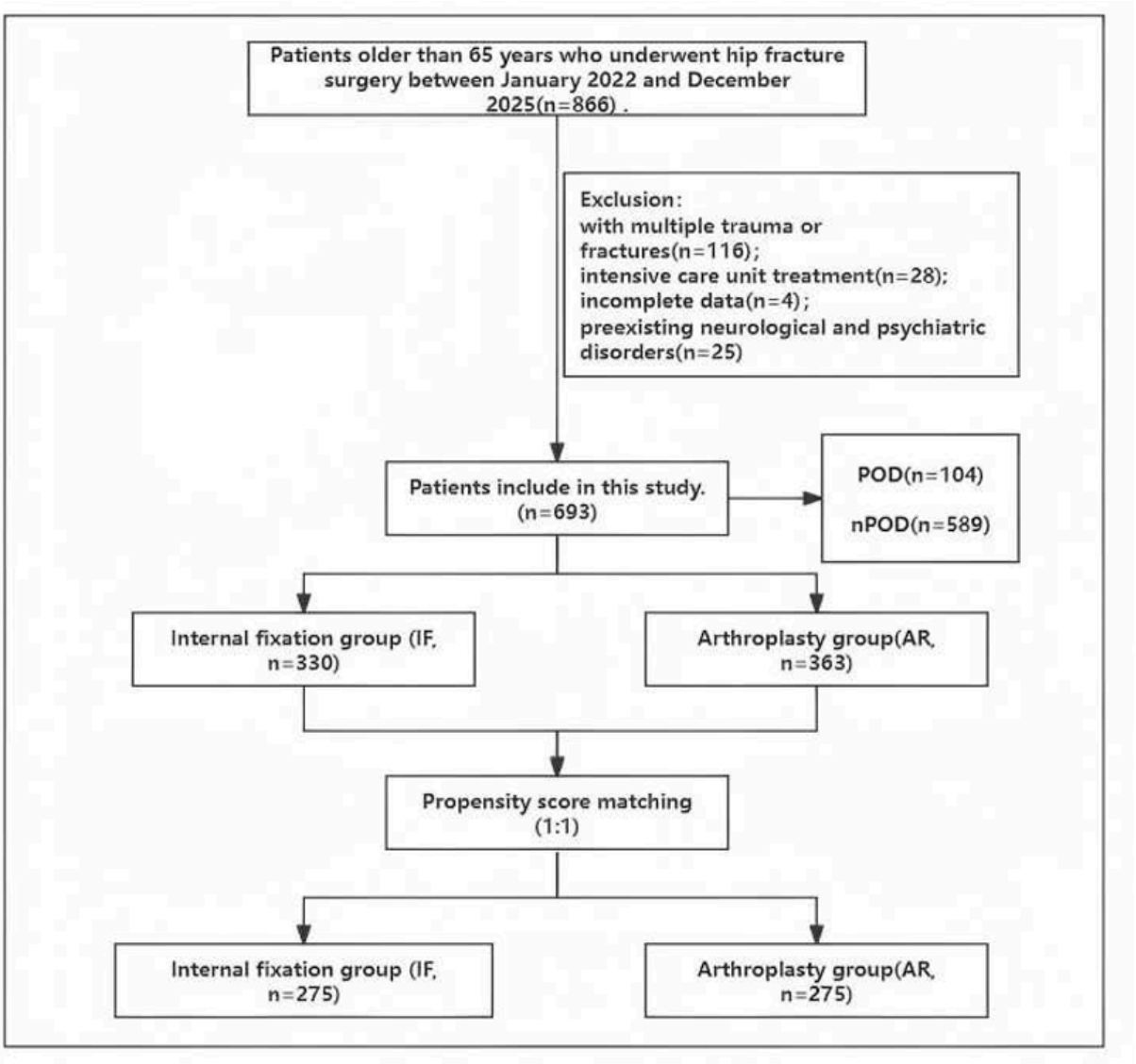



**Figure 1**

Flowchart of the research design.

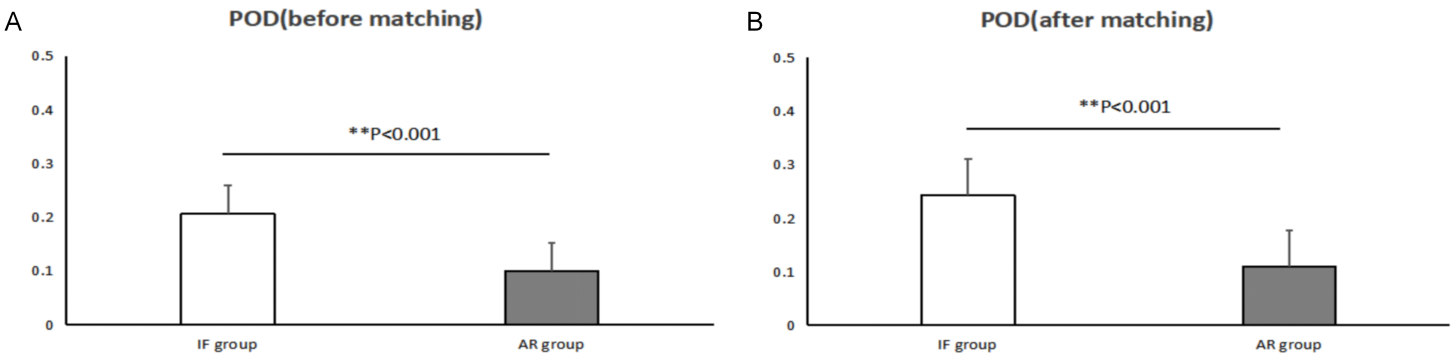
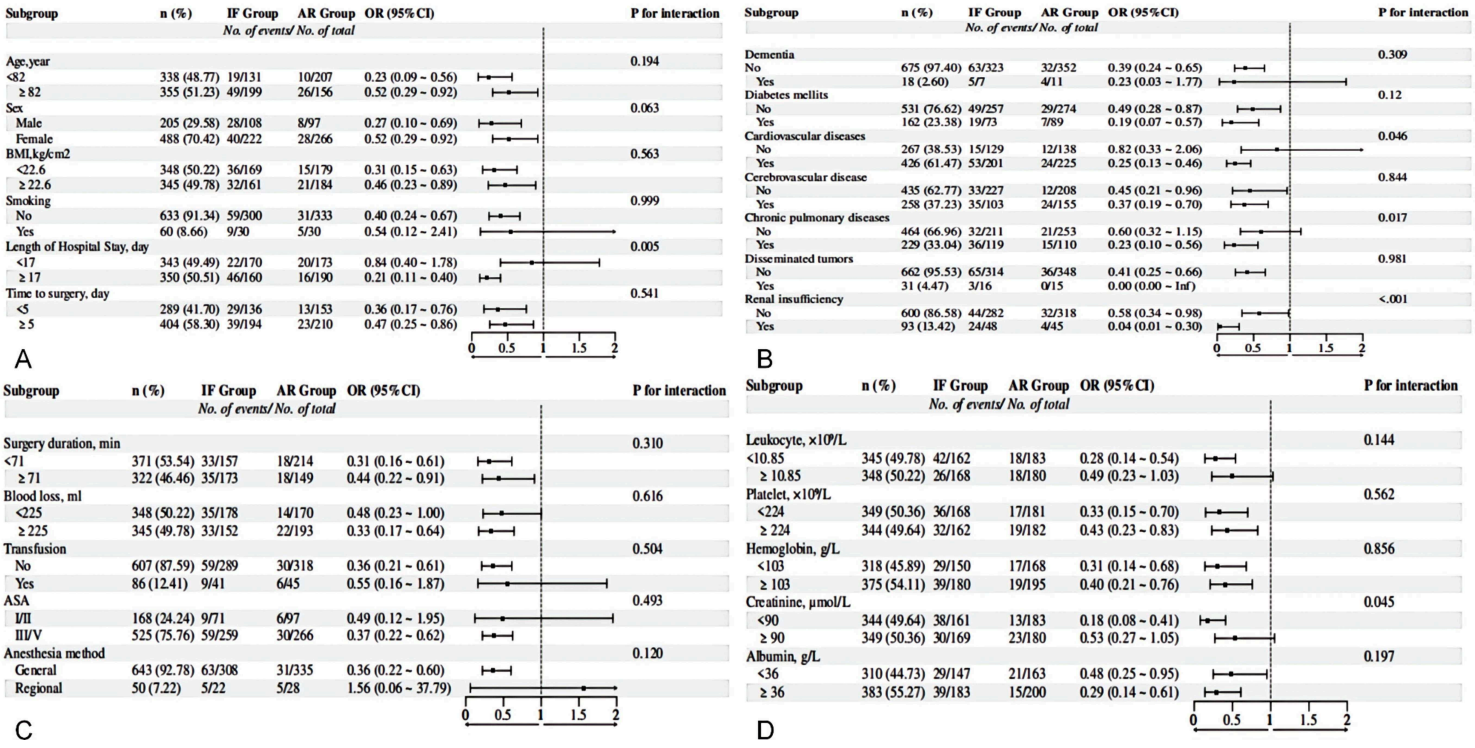



**Figure 2**

The column chart illustrates the incidence of POD in the two groups. (A) before matching; (B) after matching.




## Figure 3

A subgroup analysis was carried out to evaluate possible interactions among diverse surgical techniques and each covariate, including (A) demographic factors, (B) comorbidity factors, (C) surgery - associated factors, and (D) preoperative lab test factors.