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Effect of different analgesic treatments on the pulmonary function in elderly hip fracture patients
A prospective study

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Abstract

Background: To investigate the effect of different analgesic methods on lungs in elderly patients with hip fractures.

Methods: A prospective study was conducted on 78 elderly hip fracture patients undergoing spinal anesthesia for surgery, where 3 analgesic methods were used: postoperative Patient-controlled intravenous analgesia pump (PCIA) (group I), pre and postoperative PCIA (group II), and preoperative fascia iliaca compartment block (FICB) + postoperative PCIA (group III). The following indicators were monitored at admission (T_1), on the day of surgery before anesthesia (T_2), and 7 days after surgery (T_3): heart rate (HR), respiratory rate (RR), forced expiratory volume during the first second, arterial partial pressure of oxygen (PaO_2) and carbon dioxide ($PaCO_2$), C-reactive protein (CRP), and interleukin 6 (IL-6). Pulmonary complications such as pulmonary atelectasis and respiratory insufficiency were analyzed.

Results: The HR, RR, forced expiratory volume during the first second, PaO_2, $PaCO_2$, IL-6, and CRP levels at T_1 after fracture did not significantly differ among the 3 groups ($P > .05$). After different analgesic treatments post-admission, all indicators at T_2 were significantly higher in group I than in groups II and III ($P < .05$), while there was no significant difference between groups II and III ($P > .05$). At T_3, there were no significant differences in RR, HR, PaO_2, $PaCO_2$, and CRP levels among the groups ($P > .05$), but IL-6 levels at T_3 were significantly higher in group I than in groups II and III ($P < .05$).

Conclusion: The use of effective pain relief during surgery can help protect the lung function of elderly patients with hip fractures. When using PCIA with FICB before surgery, respiratory performance may be better protected compared to using unsustained analgesia. This could be due to a decrease in the levels of inflammatory markers such as CRP and interleukin-6.

Abbreviations: BMI = body mass index, CRP = C-reactive protein, ERAS = Enhanced Recovery after Surgery, FEV_1 = forced expiratory volume during the first second, FICB = fascia iliaca compartment block, FiO_2 = fraction of inspiration oxygen, FVC = forced vital capacity, HR = heart rate, IL-6 = interleukin 6, NSAIDS = Non-Steroidal Anti-Inflammatory Drugs, $PaCO_2$ = carbon dioxide, PaO_2 = arterial partial pressure of oxygen, PCIA = patient-controlled intravenous analgesia pump, RR = respiratory rate, TPVB = thoracic paravertebral block, VAS = visual analogue score.

Keywords: analgesia, fascia iliaca compartment block, hip fracture, lung, Patient controlled intravenous analgesia

1. Introduction

As the world's population ages, hip fractures have become the most common type of traumatic disease in elderly patients. According to statistics, about 1.6 million elderly patients suffer from such trauma every year worldwide, and this figure is increasing by 25% every 10 years.[1] In recent years, the number of hip fractures in the elderly has gradually increased and has become a core condition in trauma orthopedics. The incidence of preoperative hypoxemia after the fracture is about 23.8%,[2] with a high incidence of pulmonary complications and high morbidity and mortality in these fractures. The hip fracture has a significant mortality and morbidity rate due to fragility and comorbidity.[3] Elderly patients' organ function is gradually deteriorating. The hazards of surgery are naturally enhanced in the context of chronic systemic disorders. As a result, extra consideration should be given to the perioperative treatment of older patients.[4] Hip fractures are characterized by significant preoperative and postoperative pain, with severe pain throughout the perioperative period, therefore increasing the patient's cardiopulmonary load and increasing the incidence of

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postoperative complications and mortality. After hip arthroplasty, about 6% of patients will continue to feel severe pain, and post-arthroplasty pain can be caused by a variety of reasons.[5]

Timely and effective postoperative analgesia can help promote early recovery of injured limb function and reduce the occurrence of postoperative complications, especially with the rise and popularity of Enhanced Recovery After Surgery (ERAS), so perioperative analgesia has received special attention and more emphasis is now placed on the full in-hospital coverage of analgesic treatment, i.e., the analgesic treatment procedure is initiated from the time the patient is admitted to the emergency room.[6] The ERAS protocol relies heavily on effective postoperative analgesia and early functional exercise.[7] Intravenous opioids, local epidural anesthetics, peripheral nerve block, and local infiltration anesthesia are currently the most routinely utilized analgesic treatments in orthopedic surgery.[8] Elderly patients who experience hip fractures often undergo trauma, leading to various forms of distress, pain, and stress. These conditions can result in certain physiological responses such as an accelerated heart rate, shallow and rapid breathing, hyperventilation, or carbon dioxide retention. Additionally, the inflammatory response markers C-reactive protein (CRP) and IL-6 tend to increase to varying degrees. Managing these symptoms effectively is crucial in alleviating pain, minimizing the impact on lung function caused by surgery, and reducing the occurrence of postoperative complications. Currently, both domestic and international approaches to pain management during the period from admission to pre-operation commonly involve the use of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs), opioids, and other systemic analgesics. However, these methods have limitations, and the effectiveness of different analgesic techniques can vary. Moreover, these diverse approaches may have differing effects on lung function.[9,10]

However, there are fewer national and international reports on the effects of different analgesic modalities and different analgesic methods on altered pulmonary function after the hip fracture in the elderly, and how the inflammatory factors released after hip fracture, especially those causing acute lung injury, are affected. According to Abrahamsen and Nrgaard's comprehensive study of senior patients' perspectives on treatment, care, and rehabilitation after a hip fracture, the preoperative pain reported by patients with hip fractures was significant and intense.[11] Some participants claimed that the analgesic impact of pain medication was the reason for pain management success. Pain medication was mentioned as a reason for well-managed pain, but some patients claimed that pain relief did not reduce pain and that opioids caused nightmares, hallucinations, and worry about death, prompting them to refuse pain relief.[12]

The downsides of intravenous administration include high dosage, limited analgesic efficacy, and the possibility of severe postoperative nausea and vomiting.[13] This paper prospectively analyzes the effects of different analgesic methods on pulmonary function after the hip fracture in the elderly.

2. Materials and methods

2.1. Inclusion criteria

From August 2020 to August 2022, a total of 239 patients over 60 years of age with hip fractures and hip surgery under spinal anesthesia were performed in our hospital in this prospective study. 118 patients with severe comorbidities and underlying diseases were excluded, and a total of 121 patients with hip fractures who were admitted to the hospital within 3 days of the fracture and did not have any serious complications were included in the study, and they underwent delayed hip joint surgery. This study was approved by our institutional ethical committee (No. 2020-07-02). Each patient gave written informed consent for this study. The surgical techniques used in the study consisted of femoral head replacement, hip replacement, proximal femoral nail anti-rotation, as well as a proximal femoral nail.

2.2. Exclusion criteria

Admission for more than 3 days after the fracture, long-term smoking, stroke, severe chronic obstructive pulmonary disease, heart failure, respiratory failure, severe anemia, severe hepatic and renal insufficiency, co-infectious disease, and severe cognitive impairment were excluded. Epidural analgesia was excluded because it was not convenient for the patient to move off the floor early. Those with comorbidities such as diabetes mellitus, coronary artery disease, hypertension, etc. that did not significantly cause functional impairment were not excluded.

118 cases of severe complications and underlying diseases were excluded, as follows: There were 12 cases of coronary heart disease complicated with cardiac failure, 59 cases of severe obstructive ventilation dysfunction of Chronic obstructive pulmonary disease (COPD) (including 41 cases of long-term smoking for more than 20*20 years), 9 cases of sequelae of stroke, 11 cases of hemoglobin less than 7 g/L, 10 cases of severe cognitive impairment, 6 cases of hemodialysis, 2 cases of silicosis complicated with pulmonary tuberculosis. Cerebral apoplexy complicated with severe cognitive impairment and pulmonary infection in 4 cases, coronary heart disease complicated with chronic heart failure and chronic respiratory failure in 13 cases as well.

2.3. Patient grouping

The patients were divided into 3 groups according to the different methods of perioperative analgesia: Group I: postoperative Patient-controlled intravenous analgesia pump (PCIA) in a total of 45 patients; Group II, PCIA given both on pre and postoperatively in a total of 38 patients, and Group III, fascia iliaca compartment block (FICB) given preoperatively and PCIA given postoperatively in 38 patients. The patients' or their families' informed permission was provided.

2.4. Anesthesia administration and analgesia

All patients were given intraspinal anesthesia, punctured at L2-3 or L3/4, and given 15 to 20 mg (7.5 mg/mL) ropivacaine hydrochloride in the subarachnoid space. The plane level was maintained below T8. All patients received 2 L/min of oxygen during the operation and 2 L/min of oxygen for 3 days after surgery.

Details are as follows: PCIA was formulated as sufentanil 100 μg + dizocine 15 mg + granisetron hydrochloride 6 mg + dexamethasone 20 mg + 200 mL of saline for injection (4 mL/h, additional 4 mL at 15 minutes). FICB was performed by ultrasound-guided-post placement method administered with ropivacaine 0.2% at dosage rates of 12 mL/h. The analgesic effect was evaluated by visual analogue score (VAS).

In group I, continuous analgesic drugs were not given before surgery, and analgesia with PCIA for 48 hours immediately after surgery: the PCIA formula was Sufentanil 100 μg + Dizocine 15 mg + granisetron hydrochloride 6 mg + dexamethasone 20 mg + water for injection 200 mL (background dose 4 mL/h, additional 4 mL for 15 minutes).

In Group II, the same formulation and background dose of PCIA was administered immediately after admission with the consent of the patient or his family, followed by preoperative examination and preparation after analgesia and continued PCIA for 48 hours after surgery.

In group III, patients or their family members agreed to receive continuous iliac fascia block immediately after admission with ultrasound-guided iliac fascia puncture and catheter placement. Iliac fascia block was performed with ultrasonic tie method and posterior iliac fascia block catheter placement, ropivacaine 600 mg + normal saline 300 mL (load 20 mL, 12 mL/h). The analgesic effect was evaluated by visual analog VAS with a score of less than 3. After analgesia took effect, preoperative preparation and examination were carried out until surgery, and PCIA was continued with the same drugs and methods in group I for 48 hours after surgery.

2.5. Primary outcome and secondary outcome

The study monitored several primary outcomes including heart rate (HR), respiratory rate (RR), forced expiratory volume during the first second (FEV_1) measured by the CHESTGRAPH HI-101 (which is the simplest index for patients to complete), non-oxygenated arterial partial pressure of oxygen (PaO_2), partial pressure of carbon dioxide ($PaCO_2$). Due to the difficulty of completing pulmonary function tests in most elderly patients, especially after trauma and the high variability of the data, FEV_1 was determined by the maximum value of the 3 tests.

The secondary outcomes included CRP and interleukin 6 (IL-6).

The measurements of the above indicators were taken at 3 specific time points: upon admission to the hospital (T_1), on the day of surgery prior to anesthesia (T_2), and 7 days after surgery (T_3). The occurrence of complications such as postoperative pneumonia, pulmonary atelectasis, and pulmonary respiratory insufficiency were analyzed.

2.6. Statistical analysis

The normally distributed measurement data represented as Mean ± SD were analyzed repeated-ANOVA-post hoc test using SPSS17.0 (SPSS, Inc., Armonk, NY). Fisher Exact test was performed for the incidence of adverse events. In determining the required sample size to achieve $1–\beta = 0.80$ and $\alpha = 0.05$, an one-way ANOVA test was conducted and the statistical power results indicated that a minimum of 25 subjects were required in each group. The two-tailed test, $P < .05$ was used to determine statistical significance.

3. Results

3.1. Comparison of general conditions of patients in the 3 groups

After excluding the lost follow-up patients, complete data were obtained for all 3 groups of 78 cases (Fig. 1). Complete data were obtained for all 3 groups of 121 cases including 45 men and 76 women, aged 60 to 95(78.09 ± 9.59) years, VAS was 7.08 ± 1.02. An average hospital stay was 11.55 ± 1.78 (Including preoperative preparation time and partial early postoperative rehabilitation and hospitalization). Group I was (78.48 ± 8.99) years old and weighed (59.12 ± 13.85) kg and VAS 7.08 ± 0.98, group II was (80.12 ± 9.40) years old and weighed (57.88 ± 14.09) kg VAS 7.19 ± 0.90, and group III was (75.81 ± 10.75) years old and weighed (55.88 ± 13.23) kg as well VAS 6.96 ± 1.18. All patients received spinal anesthesia during surgery, and those with serious complications (including pulmonary disease) or very poor lung function were excluded prior to surgery. There were no statistically significant differences in the pulmonary function indicators, age, weight, and VAS between the groups upon admission ($P > .05$) (Table 1).

3.2. Effect of different analgesic methods on each index

The RR showed significant differences between Group I and Group III at T1 and T2 (22.58 ± 3.38 vs 22.69 ± 3.15, $P = .010$; 21.15 ± 2.27 vs 16.38 ± 2.82, $P < .001$, respectively). Regarding HR, Group I differed significantly from Group II and Group III at T2 (86.92 ± 9.87 vs 70.88 ± 7.70, $P < .001$; 86.92 ± 9.87 vs 71.64 ± 5.27, $P < .001$, respectively). Group II also differed significantly from Group III at T2 (70.88 ± 7.70 vs 71.64 ± 5.27, $P < .001$). FEV_1 showed a significant difference between Group I and Group II at T2 (1.05 ± 0.25 vs 1.21 ± 0.26, $P = .041$). Arterial oxygen partial pressure (PaO_2) demonstrated significant differences between Group I and Group II at T1 and T2 (79.01 ± 7.71 vs 84.79 ± 8.54, $P < .001$; 79.01 ± 7.71 vs 87.53 ± 7.35, $P < .001$) as well as between Group I and Group III at T2 (79.01 ± 7.71 vs 85.17 ± 11.94, $P < .001$). Group I (n = 26), Group II (n = 26), and Group III (n = 26) were assessed for interleukin-6 (IL-6) and CRP levels at different time points. The IL-6 levels in Group I were 16.84 ± 19.02 pg/mL, while Group II exhibited higher levels at T2 (22.37 ± 20.25, $P < .05$) and Group III showed lower levels at T2 (11.56 ± 9.50, $P < .05$). For CRP, Group I had levels of 22.74 ± 18.44 mg/L, Group II had lower levels at T2 (21.88 ± 9.97, $P < .05$), and Group III had higher levels (29.40 ± 14.85). Additionally, significant differences were observed between Group I and Group II at T2 for IL-6 ($P = .047$) and CRP ($P < .001$). Group III also differed significantly from Group II at T2 for CRP ($P < .001$) (Table 2). Significant changes were observed in the majority of indexes in each group of patients receiving different analgesia in the perioperative period, except for $PaCO_2$. This suggests that providing adequate analgesia through PCIA or nerve block techniques like FICB as early as possible after admission is preferable over preoperative intermittent analgesia or no analgesic medication, as it offers better lung and respiratory function protection.

Intra-group comparisons at different time points and inter-group comparisons at each time point revealed no statistically significant differences in HR, RR, FEV_1, arterial oxygen partial pressure (PaO_2), arterial carbon dioxide partial pressure ($PaCO_2$), interleukin-6 (IL-6), and CRP levels at T1 ($P > .05$). At T2, group I exhibited significantly higher values for each index compared to groups II and III, while there were no statistical differences between groups II and III ($P > .05$). However, there were no statistically significant differences in HR, RR, IL-6, and CRP levels, and elevated FEV_1 and PaO_2 at T1 and T3 compared to group I ($P > .05$).

According to Table 2, the results of the intra-group comparisons revealed significant differences when comparing T1 with the other time points (T2 and T3) in all groups ($P < .001$). Additionally, in groups II and III, there were significant differences between T1 and T2 ($P < .001$). Furthermore, the inclusion of the additional data point (⑥) indicated a statistical difference between T3 and T2 specifically in group I ($P < .001$), when conducting an intra-group comparison between T2 and T3. However, there was no statistical difference observed between T3 and T2 in the other 2 groups.

3.3. Clinical outcome

The patients had an average hospital stay of 11.55 ± 1.78 days, and there were no fatalities in any of the 3 groups. The incidence of nausea and vomiting during analgesia did not differ significantly between the groups ($P > .05$), with 7, 6, and 4 cases reported in Groups I, II, and III, respectively. Postoperative pulmonary complications were observed in 13, 7, and 6 cases of pulmonary atelectasis, including discoid pulmonary atelectasis, with a significant difference ($P > .05$) between Group I and Groups II and III. The number of cases of respiratory insufficiency was 5, 2, and 1 in Group I, II, and III, respectively. Detailed comparative results of each group are presented in Table 3. Pulmonary insufficiency was significantly higher in Group I than in Groups II and III ($P = .027$), while respiratory insufficiency was significantly higher in Group I than in Groups II and III ($P = .040$). There was no significant difference in complications between Groups II and III (Table 3).

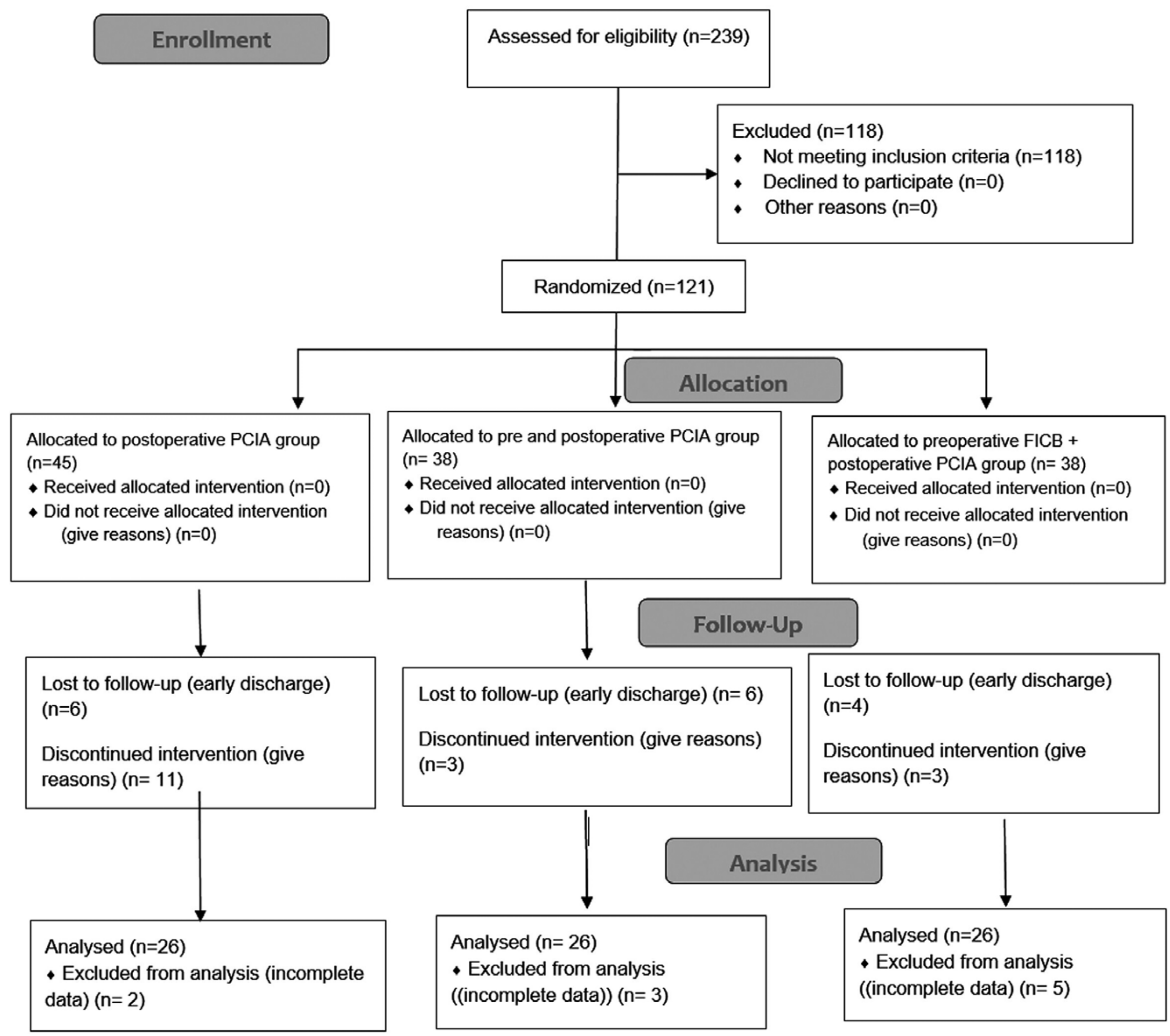

Figure 1. The enrollment flow chart of the included patients. FICB = fascia iliaca compartment block, PCIA = patient-controlled intravenous analgesia pump.

Table 1

Comparison of general conditions of patients in the 3 groups.

	Group I (n = 45)	Group II (n = 38)	Group III (n = 38)	*P*
Age (yr)	78.48 ± 8.99	80.12 ± 9.40	75.81 ± 10.75	.707
Weight (kg)	59.12 ± 13.85	57.88 ± 14.09	55.88 ± 13.23	.625
VAS score	7.08 ± 0.98	7.19 ± 0.90	6.96 ± 1.18	.778

VAS = visual analogue score.

4. Discussion

Hip fractures have become the most common type of traumatic disease in elderly patients in clinical practice, and the incidence of complications of these fractures is high, as are the rates of disability and death, which are as high as 31.3% to 36% within 1 year,[14–16] and this high mortality rate can persist up to 10 years after the injury.[17] Many patients lose the ability to care for themselves after a hip fracture.[18–20] The absence of perioperative deaths in our study may be due to the fact that patients with preoperative comorbidities such as cardiopulmonary failure and hepatic and renal dysfunction have been excluded. Wei and Wu et al[21,22] showed by logistic regression analysis that advanced age and prolonged preoperative bed rest were independent risk factors for new postoperative pulmonary complications in elderly hip fracture patients.

The number of pulmonary segments with postoperative pneumonia pneumonia occurred in the 3 study groups were 24, 11, and 9 cases respectively, with statistical differences between the groups ($P < .05$). While the number of final respiratory insufficiency cases was 5, 2, and 1 cases respectively, there was no statistical difference between the groups ($P > .05$), the possible reason for this is the application of multimodal analgesia in the 3 groups of patients, thus effectively relieving postoperative pain and damage to pulmonary function from surgery, reducing the incidence of postoperative complications and being able to reduce the rate of postoperative pulmonary infection in patients, which is consistent with the literature report.[23] However, the effect of the small number of cases, the exclusion of comorbidities and patients with low functional status, and the timely and adequate postoperative chest physiotherapy and respiratory therapy cannot be excluded.

Current studies have concluded that complications after hip fracture are an absolute factor affecting morbidity and mortality, and pulmonary complications dominate among all

Table 2

Effect of different analgesic methods on each index.

	Group I (n = 45)			Group II (n = 38)			Group III (n = 38)			
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	*P*
RR (breaths/min)	22.58 ± 3.38	21.15 ± 2.27②③⑤⑥	15.08 ± 1.90①②③⑥	22.69 ± 3.15	16.38 ± 2.82①②④	15.31 ± 1.57①②	24.15 ± 3.63	16.69 ± 2.63①③④	15.27 ± 2.24①③	.010
HR (bpm)	89.20 ± 15.58	86.92 ± 9.87②③⑤⑥	69.12 ± 6.55①②③⑥	84.60 ± 20.25	70.88 ± 7.70①②④	70.92 ± 2.93①②	87.56 ± 18.24	71.64 ± 5.27①③④	68.60 ± 4.23①③	<.001
FEV_1 L/min)	0.98 ± 0.32	1.05 ± 0.25②③⑤⑥	1.25 ± 0.27①②③⑥	0.95 ± 0.36	1.21 ± 0.26①②④	1.31 ± 0.26①②	0.97 ± 0.35	1.27 ± 0.32①③④	1.34 ± 0.32①③	.041
PaO_2 (mm Hg)	70.17 ± 9.60	79.01 ± 7.71②③⑤⑥	86.60 ± 8.61①②③⑥	68.35 ± 8.13	84.79 ± 8.54①②④	87.53 ± 7.35①②	67.82 ± 7.23	85.17 ± 11.94①③④	86.70 ± 11.09①③	<.001
$PaCO_2$ (mm Hg)	37.12 ± 8.06	36.98 ± 4.22②③⑤	37.64 ± 2.98①②③	37.38 ± 7.64	37.43 ± 2.96①②④	38.83 ± 3.13①②	37.52 ± 8.54	37.60 ± 3.26①③④	38.30 ± 3.38①③	.773
IL-6 (pg/mL)	16.84 ± 19.02	22.3 7 ± 20.25②③⑤⑥	11.56 ± 9.50①②③⑥	12.99 ± 24.81	6.03 ± 5.32①②④	4.54 ± 6.10①②	22.14 ± 29.86	9.59 ± 11.16①③④	5.93 ± 8.04①③	.047
CRP (mg/L)	22.74 ± 18.44	21.88 ± 9.97②③⑤⑥	11.74 ± 7.85①②③⑥	29.40 ± 14.85	13.03 ± 6.97①②④	7.21 ± 5.94①②	25.53 ± 14.16	14.89 ± 8.52①③④	7.53 ± 5.82①③	<.001

CRP = C-reactive protein, FEV_1 = forced expiratory volume during the first second, HR = heart rate, IL-6 = interleukin 6., $PaCO_2$ = arterial partial pressure of carbon dioxide, PaO_2 = arterial partial pressure of oxygen, RR = respiratory rate.
①Intra-group comparison with T_1, $P < .001$.
②Group I compared with Group II, $P < .001$.
③Group I compared with Group III, $P < .001$.
④Group II compared with Group III, $P < .001$.
⑤Group I compared with (Group II + group III), $P < .001$.
⑥ Intra-group I comparison with T2 and T3, $P < .001$.

Table 3

Comparison of the occurrence of complications in each group.

	Group I (n = 45)	Group II (n = 38)	Group III (n = 38)	*P*
Pulmonary atelectasis (cases)	13 P1 P2 P3	7 P1 P4	6 P2 P4	.000
Respiratory insufficiency (cases)	5 P3	2 P4	1 P4	.642
Nausea and vomiting (cases)	7	6 P4	4 P4	.641

P1: Group I compared with Group II, $P < .05$.
P2: Group I compared with Group III, $P < .05$.
P3: Group I compared with Group II and Group III): $P < .05$.
P4: Group II compared with Group III, $P > .05$ for each complication.

complications,[24] and some scholars[25–27] found that hip fracture is thought to induce acute lung injury in aged rats, and pulmonary malfunction is a key link in initiating multi-organ failure, and postoperative distal organ lung injury is a complication after various surgeries and is associated with short- and long-term mortality and morbidity.[27]

In this study, we found that trauma, pain, and stress after the hip fracture in elderly patients led to a general increase in HR, tachypnea, hyperventilation or carbon dioxide retention, and varying degrees of elevation in inflammatory response indicators CRP and IL-6, all of which improved after effective analgesic treatment. Age and the age-related phenomena of "inflammaging" appeared to be an independent risk factor exacerbating and hastening cardiac changes after the hip fracture.[10] The incidence of postoperative heart failure is relatively high in older patients with hip fractures, which is the result of a combination of high-risk factors.[28]

The results of this study showed that there were no statistically significant differences in HR, RR, FEV_1, PaO_2, $PaCO_2$, IL-6, and CRP in each group at T_1 after fracture ($P > .05$). Each monitoring index at T_2 did not improve significantly in group I versus admission at T_1, and even some patients had a tendency to deteriorate.

The performance of each index was higher in groups II and III than in groups II and III at T_2 compared with T_1 ($P < .01$), but there was no statistically significant difference between groups II and III ($P > .05$), and the HR, RR, FEV_1, and PaO_2 were significantly improved at T_3 1 week after surgery regardless of the analgesic method ($P < .01$).

Trauma, anesthesia, and postoperative severe pain can induce a robust stress response in the body. Acute pain triggers the activation of the hypothalamic-pituitary-adrenal (HPA) axis, which in turn stimulates hypothalamic neurons to secrete stress hormones such as norepinephrine (NE), cortisol (Cor), and CRP. These stress hormones are considered time-phase response proteins associated with the inflammatory response.[29]

Among these markers, the level of interleukin-6 (IL-6) shows the most significant increase following trauma and 8 to 24 hours after surgery. IL-6 is an important cytokine involved in the inflammatory response. Measurement of serum levels of CRP and IL-6 can serve as indicators to assess the extent of stress and inflammatory response in the body.[30,31] These biomarkers provide valuable information about the physiological impact of trauma and surgery on the patient's overall condition.

The study findings demonstrated that effective analgesia led to a significant reduction in the stress response. In group I, where preoperative analgesia was insufficient, there was no notable difference between T2 and T1, and there was even a tendency for an increase in stress response. However, after immediate postoperative effective analgesia, T3 showed a significant decrease in stress response. At T3, the inflammatory markers IL-6 and CRP in group I were significantly higher compared to groups II and III, indicating a lingering difference in the stress and inflammatory response. In contrast, the relevant indicators in groups II and III exhibited a downward trend at T2 after admission to the hospital, possibly due to the timely administration of effective analgesia. These findings suggest that timely and effective analgesia can alleviate the stress response in patients. Moreover, it highlights the importance of adequate analgesic interventions to manage stress and inflammation, as insufficient preoperative analgesia may lead to increased stress response.

The CRP at T_3 was significantly higher in all 3 groups compared with T_1 and T_2 ($P < .001$), suggesting that the trauma of surgery and anesthesia reactivated the release of inflammatory factors, but the degree of increase was statistically different in group I compared with groups II and III ($P < .05$), while there was no statistical difference in groups II and III ($P > .05$). Combined with the decreased CRP and IL-6 at T_2 and T_3 in groups II and III, it was suggested that the use of continuous intravenous PCIA or FICB could achieve good analgesic effects, and it might be more effective to inhibit the expression of inflammatory mediators by antagonizing stress while maintaining analgesia throughout the perioperative period. Moreover, the differences in IL-6 and CRP at T_3 in group I and groups II and III still existed ($P < .01$), which may be related to the preoperative pain, longer duration of stress, and longer duration of inflammatory mediator expression. Current pain management from admission to the preoperative period in China and abroad usually relies on systemic analgesic drugs such as NSAIDs and opioids, but the effect is limited, while it has also been shown that CRP levels may be elevated in the opioid-induced pro-inflammatory state.[32,33]

The FICB is a recently discovered technique that is mostly utilized in surgeries on the lower limbs.[34] Local anesthetics are delivered to the FICB. Standard analgesia mixed with FICB considerably decreased the VAS ratings of patients with femoral neck fractures following surgery, according to Williams et al[35] For geriatric patients with femoral neck fractures, Yun et al[36] compared the effectiveness of FICB with that of spinal anesthesia in a 2009 RCT. Results showed that patients who received FICB had greater patient acceptability than controls, a mean VAS score that was lower during positioning, and a mean time to attain SA that was shorter. The FICB therapy enhanced sleep quality, lowered inflammatory markers in the serum, and decreased postoperative pain.[37] In this group, due to the poor ability of the elderly to cooperate with the determination of pulmonary function after trauma, the results of pulmonary function testing were affected, and at the same time, due to pain or tension, early tachypnea, shortened expiratory time, restricted forceful breathing or even sudden interruption of expiration, FEV_1 was significantly lower than normal, and gradually recovered with the release of pain.

$PaCO_2$ did not differ significantly between groups and within groups at any time, mainly due to the large dispersion at T_1. In some patients, hyperventilation due to pain led to reduced FEV_1, and in some patients, fear of pain led to reduced tidal volume and reduced FEV_1, resulting in carbon dioxide retention, and the RR and depth of breathing were restored after the administration of analgesia. FICB increased the quality of recovery at 24 hours and decreased pain levels in older patients who had total hip arthroplasty compared to PCIA.[38] Nie et al[39] investigated the effects of fentanyl PCIA and FICB on postoperative analgesia for the hip fracture, and the findings indicated that patients receiving FICB experienced less pain than those receiving PCIA while experiencing no ill effects associated with nerve block. In our investigation, no negative side effects including infection, anesthetic toxicity, or nerve damage were noted. FICB is a reliable and secure analgesic method for individuals having hip surgery.

The incidence of postoperative hypotension is typically increased by sympatholytic effects of epidural analgesia that result in vasodilation, especially for patients having gastrectomy. 17 patients receiving epidurals in total had to be stopped early owing to persistent hypotension. In the patient-controlled epidural analgesia group, which is significantly more than in the PCIA group, close to 22% of patients experienced postoperative hypotension.[40] Thoracic paravertebral block (TPVB) and PCIA, according to Yeying et al,[41] effectively relieved pain. At rest and when coughing, VAS values in the TPVB group were substantially lower than in the PCIA group ($P < .05$). In comparison to the PCIA group, patients in the TPVB group exhibited lower $P(A\text{-}a)O_2$ and higher PaO_2 and PaO_2/Fraction of inspiration oxygen (FiO_2) FiO_2 values. Additionally, patients in the TPVB group had lower complications and higher forced vital capacity (FVC), FEV_1/FVC, and peak expiratory flow rate compared to the PCIA group ($P < .05$). Extra attention is now being paid to perioperative analgesia, with more emphasis now being placed on full coverage of analgesia throughout the in-hospital treatment process, that is, analgesic procedures are initiated first from the moment the patient enters the emergency room.[6]

We found that there was still a statistical difference in the incidence of adverse outcomes between group I and groups II and III. With the exception of dizziness ($P = .042$), Gao et al[38] identified no intergroup differences between FICB and PCIA in the number of patients requiring rescue analgesics, adverse events, the incidence of postoperative complications, duration of first postoperative ambulation, or length of hospital stay. While the implementation of continuous FICB in group III in this study could significantly relieve the pain of elderly hip fracture patients and achieve analgesic effects similar to those in group II. Continuous FICB is a reliable method with high patient satisfaction, and it can significantly relieve the pain of elderly hip fracture patients and reduce the use of opioids and adverse reactions during hospitalization, making it the first-line analgesic treatment of choice.[42]

There was no significant difference in the occurrence of nausea and vomiting among all 3 groups of patients, which may be related to the reduction in the dosage of relevant drugs by using intravenous PCIA drug combinations with the potent opioid sufentanil compounded with the opioid receptor agonist-antagonist diazoxide.[43,44] Due to the small number of cases, further observational studies are needed.

The current study has several drawbacks that should be acknowledged. Firstly, the use of the same medication dose across patients with varying body mass index (BMI) may not accurately reflect the study's findings. The lack of BMI data due to the limited number of cases, particularly in obese patients, further limits the analysis of BMI's impact on the study outcomes. Future research with a larger sample size and a diverse range of participants, including individuals with obesity, is necessary to explore the potential effects of BMI on the observed outcomes. Secondly, the study did not assess the long-term quality of recovery, which is an essential aspect to consider in evaluating the overall effectiveness of interventions. Thirdly, important outcome measures such as the duration to initial ambulation, length of hospital stay, patient satisfaction, and other relevant indicators for assessing the effectiveness of ERAS were not evaluated in this study. Lastly, elderly patients often face challenges in completing pulmonary function tests, especially when experiencing pain. This difficulty may impact the accuracy and availability of data, making it challenging to obtain or accurately measure parameters such as FVC/Forced Expiratory Volume in 1 second (FEV_1). Consequently, FEV_1 was used as an observational indicator due to its relative ease of completion. Given these limitations, it is important to interpret the study's findings cautiously and recognize that they may not directly apply to populations with higher BMI. Further research is warranted to address these drawbacks and gain a more comprehensive understanding of the topic.

5. Conclusion

Efficient pain management during the perioperative period has a beneficial effect on the respiratory function of elderly patients with hip fractures, and administering PCIA with a FICB before surgery may offer greater protection to their breathing capacity compared to temporary pain relief. This could be attributed to the potential reduction of inflammatory markers such as CRP and interleukin-6.

Author contributions

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