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The effect of pericapsular nerve group (PENG) block on postoperative analgesia in elderly patients who underwent proximal femoral nail anti-rotation surgery: a prospective, randomized-controlled trial

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Abstract

Background As a fascial plane block technique, further exploration is needed to determine the safety and efficacy of a peri-capsular nerve group (PENG) block in elderly patients with intertrochanteric femur fractures. We aimed to evaluate whether opioid consumption during a PENG block is better than a conventional opioid-based program for postoperative pain management after proximal femoral nail anti-rotation (PFNA).

Methods We conducted a prospective, randomized, controlled trial comparing the efficacy of the PENG block with the control group for elderly patients undergoing primary PFNA under general anesthesia. The primary outcome was the cumulative administration of sufentanil during the first 48 h after surgery.

Results 110 participants (55 in each group) were included in the analysis. Cumulative Sufentanil consumption between the PENG group and the control group at 48 h was 132.6 ± 12.3 vs. 141.0 ± 15.3, with a difference of -8.4; 95% CI, -13.6 to -3.1, $P = 0.002$. Sufentanil consumption at 24 h was 78.3 ± 6.1 vs. 94.0 ± 10.2, with a difference of -15.7; 95% CI, -18.9 to -12.5, $P < 0.001$. There were statistical differences in the visual analogue scale score trajectories between the two groups at 48 h postoperatively ($P < 0.001$). The median time to first remedial analgesia was lower in the PENG block group than in the control group ($P < 0.001$). However, there was no difference in the time to first standing.

Conclusion Incorporating the PENG block into a multimodal analgesia regimen can decrease opioid consumption among elderly patients undergoing PFNA under general anesthesia.

Trial registration The study was registered in the Chinese Clinical Trial Registry (ChiCTR2100054290, principal investigator: Xiao-dan, Wu, 13/12/2021).

Keywords Regional analgesia, Proximal femoral anti-rotation intramedullary nail, Pericapsular nerve group block, Pain, Opioid administration

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Introduction

Hip fracture is a common type of fragility fracture in the elderly. It is projected to reach 6.3 million by 2050 [1]. Intertrochanteric femur fracture (IFF) is a common traumatic event in elderly patients, accounting for approximately 45 to 50% of all hip fractures [2]. The proximal femoral nail anti-rotation (PFNA) is a commonly performed orthopedic procedure that aims to improve the functional status and quality of life in elderly patients with IFFs [3]. IFF often causes severe pain, limiting the ability of a patient to perform various activities, even after surgery. It also increases the risk of deep vein thrombosis, pulmonary embolism, pneumonia, and myocardial infarction [4]. Peripheral nerve block (PNB) combined with administration of a low dose of an opioid analgesic, has been widely used for perioperative analgesia in elderly hip fracture patients [5–7].

Administering a regional block analgesia in hip fracture patients is a significant challenge due to the complex innervation of the hip joint [8]. The innervation of the anterior hip capsule was examined in detail in a 2018 anatomical study by Short et al. [9]. Based on his findings, Giron-Arango et al. [10] introduced the pericapsular nerve group block (PENG block) in the same year.

As this is a relatively novel fascial plane block technique, further assessment to determine the safety and efficacy of the PENG block in elderly patients with IFF is needed. Therefore, a trial to evaluate whether opioid consumption in a PENG block is less than a conventional opioid-based program for postoperative pain management after PFNA was undertaken.

Methods

Study design

This open-label, prospective, randomized, controlled trial was approved by the institutional review board of Fujian Provincial Hospital (April 30, 2021; K2021-04–080) and was registered in the Chinese Clinical Trial Registry (ChiCTR2100054290) on 13/12/2021. The study protocol was performed in accordance with the Declaration of Helsinki and the Consolidated Standards of Reporting Trials guidelines. Written informed consent was obtained from all patients.

Participants

This study involved elderly patients who underwent elective surgical treatment for proximal femur fractures. The inclusion criteria were age $\geq$65 years, ASA grade I-III, BMI of 18–35 kg/m^2, a confirmed diagnosis of IFF, expected to have difficulties with spinal anesthesia, and an operative procedure of PFNA. The exclusion criteria were a previous history of allergy to local anesthetic drugs, either infection or anatomical variation at the puncture site, abnormalities in coagulation function, a history of previous trauma or surgery to the hip, abnormal function of vital organs, peripheral nerve disease, and a degree of mental retardation with communication impairment.

Randomization and masking

Participants in the study were randomly assigned to the PENG group or control group at a 1:1 ratio. The randomization was conducted using computer-generated random numbers. The opaque envelope used was sealed to ensure allocation concealment. The anesthesiologist and surgeon in the operating room were unaware of the group allocation, as were the postoperative care providers and outcome assessors.

Procedures

The ultrasound-guided PENG block

An experienced anesthesiologist performed the PENG block procedure in an anesthesia preparation room. The patient is administered with sedation and analgesia before block. The procedure was performed according to Giron-Arango et al. [10]. A low-frequency convex array probe was selected and positioned parallel to the inguinal ligament, slightly above the femoral head (Fig. 1A, B). Using an in-plane puncture technique from the outside (Fig. 1 C), the needle tip was guided between the psoas major tendon and the pubic bone. After ensuring no blood is drawn back, 20 mL of 0.3% ropivacaine [11, 12] was slowly injected. The diffusion of local anesthesia between the tendon and iliopubic eminence.

The patients in the control group were transferred to the block area before the operation and received the same sedation and analgesia protocol as the PENG group. However, no PENG block was performed on these subjects, instead, 'fake scan' was conducted. The post-anesthesia care unit (PACU) care, ward care as well as the rehabilitation pathway were similar for all participants.

General anesthesia procedure

Anesthesia was induced by using midazolam (0.02 mg/kg), propofol (1–1.5 mg/kg), and sufentanil (0.4 ug/kg). Cisatracurium (0.15 mg/kg) was then administered intravenously, and a laryngeal mask was placed. Total intravenous anesthesia was used to maintain the patients under anesthesia, with a propofol concentration set at 2.0–4.0 ug/mL (Marsh model), and a sufentanil concentration of 0.2 ng/mL (Gepts model). The anesthetic medication was adjusted based on the BIS, surgical Pleth index (SPI), and invasive blood pressure monitoring [13].

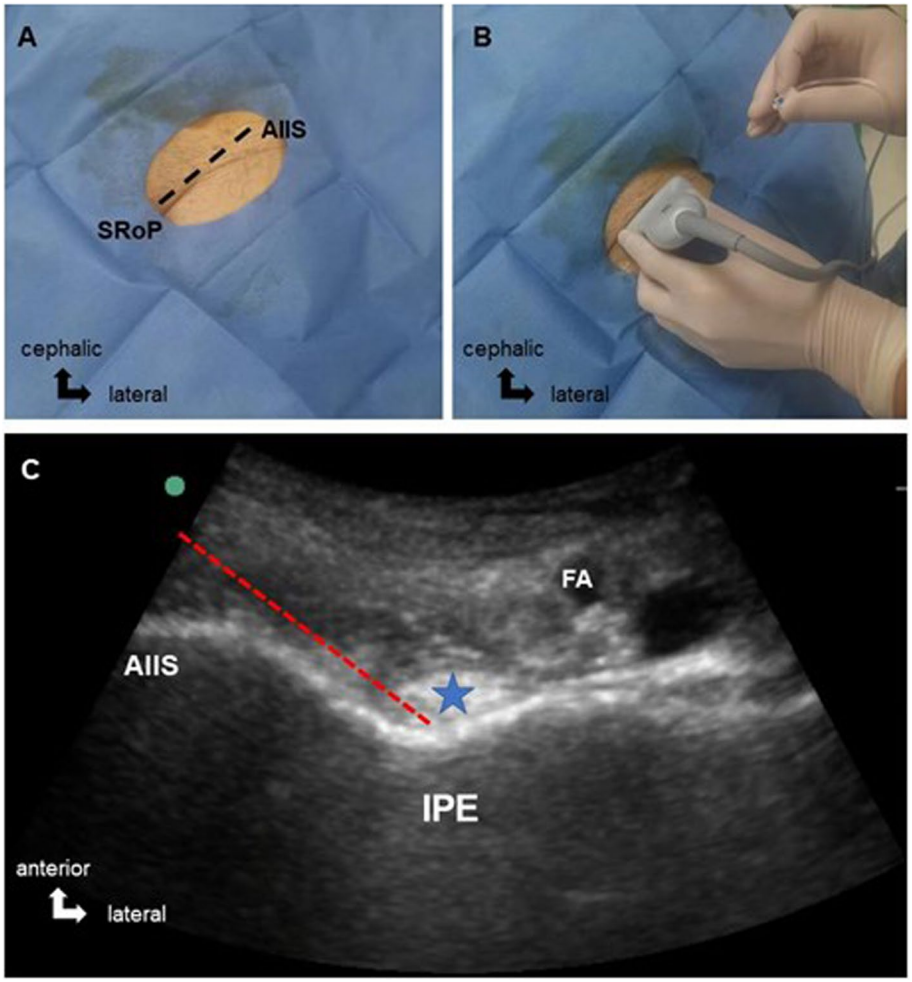

Fig. 1 Images of an ultrasound-guided pericapsular nerve group block. **A** The left hip in the supine position. **B** Orientation of the ultrasound probe. **C** The needle tip was positioned between the psoas tendon and the pubic ramus by using an in-plan approach. AIIS, anterior inferior iliac spine; FA, femoral artery; IPE, iliopubic eminence; SRoP, superior ramus of pubis; PT, psoas tendon

Postoperative analgesia management protocol

At the end of the operation, the surgeon administered 0.5% ropivacaine (15 mL) for surgical incision infiltration. Patient-controlled intravenous analgesia (PCIA) was administered to both groups: sufentanil (200 ug) + tropisetron (10 mg) + saline (150 mL), background dose (2 mL), single PCIA dose (2 mL), locking time (15 min) and maximum dose (8 mL/h). The same doctor instructed all the patients to press the PCA button when their numeric rating scale (NRS) ≥ 4 and to observe this for 15 min. If the pain could not be relieved by pressing the button twice, the ward doctor would provide the patient with oral tramadol supplementary analgesia.

Primary outcome

The primary outcome was the cumulative consumption of sufentanil during the first 48 h after surgery.

Secondary outcomes

The secondary outcomes included the cumulative consumption of sufentanil during the intraoperative period and the first 24 h after surgery. Postoperative visual analogue scale (VAS) scores (measured on a scale of 0–10) were recorded at rest and during movements at PACU, 6, 12, 24, and 48 h. Time to first standing and the time to the first postoperative remedial analgesia were also recorded, along with any block-related complications. Side effects associated with opioid use.

Sample size calculation

Based on our previous attempts, we found that the cumulative consumption of sufentanil in the PCIA at 48 h postoperatively was 140.3 ± 20.5 ug for the control group. A reduction of at least 10% is considered clinically significant [14]. PASS 15.0 software package (NCSS, LLC, Utah, US) was used to estimate the sample size, with a significance level of two side α = 0.05 and a power of (1-β) = 0.90. A total of 90 patients (45 in each group) were calculated, and with a 20% loss to follow-up, a total of 114 patients were enrolled.

Statistical analysis

This data from this study was analyzed using the mITT set. Normal distribution were expressed as means (standard deviations) and analyzed by the Student's t-test. Non-normally distributed continuous variables were expressed as medians [interquartile ranges (IQRs)] and the differences were compared using the Mann–Whitney U test. Categorical data were expressed as absolute frequencies (percentages) and compared using either the Pearson $\chi 2$ or Fisher's exact tests. For repeated measures, the linear mixed effects model was used with an unstructured covariance structure. The Kaplan–Meier curve analysis were used to compare the differences in the time of first postoperative immobilization and the time to first postoperative remedial analgesia. Statistical analysis and graphing were performed by using SPSS 22.0 and the R 4.1.0. $P < 0.05$ were considered statistically significant.

Results

A total of 114 participants were randomly assigned to either the PENG group ($n = 57$) or the control group ($n = 57$) and received the intended treatment. Two patients in each group were lost to follow-up, resulting in 55 subjects being analyzed for their primary outcomes in each group. The recruitment process is described in Fig. 2 (CONSORT flow diagram). The characteristics of the patients in the two groups were similar ($P > 0.05$) as shown in Table 1.

Primary outcome

We observed significant differences in the cumulative sufentanil consumption between the PENG and control groups at 48 h (132.6 ± 12.3 *vs.* 141.0 ± 15.3, difference: −8.4; 95% CI, −13.6 to −3.1, $P = 0.002$) (Fig. 3).

Secondary outcomes

We observed significant differences in the cumulative sufentanil consumption between the PENG and control groups at 24 h (78.3 ± 6.1 *vs.* 94.0 ± 10.2, difference: −15.7; 95% CI, −18.9 to −12.5, $P < 0.001$) (Fig. 3). Time to first standing: PENG group (31.77; 95% CI, 28.32 to 35.21) *vs.* control group (30.28; 95% CI, 27.85 to 32.71), hazard ratio: 0.82; 95% CI, 0.45 to 1.48, Log-Rank $P = 0.511$. (Fig. 4A). Time to first postoperative remedial analgesia: PENG group (16.89; 95% CI, 14.66 to 19.12) *vs.* control group (10.10; 95% CI, 8.94 to 11.27), hazard ratio: 0.49; 95% CI, 0.31 to 0.80, Log-Rank $P = 0.004$ (Fig. 4B).

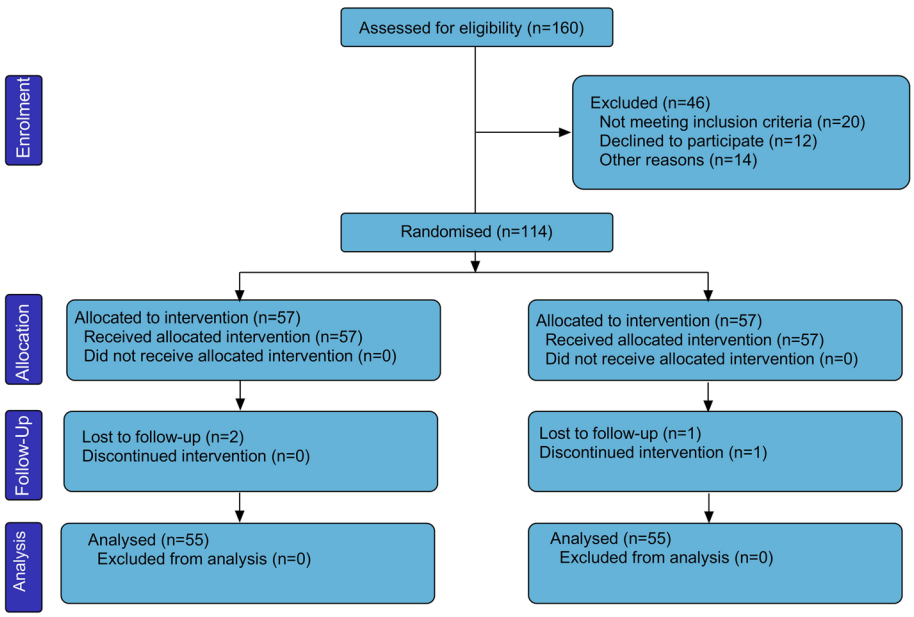

Fig. 2 The CONSORT flow diagram for this study

Table 1 The baseline characteristics and outcome

Characteristics	PENG block group ($n=55$)	Conventional group ($n=55$)	*P-value*
Age (yr)	75.40 (7.02)	76.54 (8.12)	0.433
Gender			
Male	20 (36.4)	25 (45.5)	0.438
Female	35 (63.6)	30 (54.5)	
BMI (Kg/m^2)	24.70 (3.21)	23.90 (4.01)	0.251
ASA grade			0.927
I	10 (18.2)	9 (16.4)	
II	15 (27.3)	14 (25.5)	
III	30 (54.5)	32 (58.1)	
Length of preoperative stay (h)	50 [18,70]	54 [20,74]	0.091
aCCI	6.4 (1.2)	5.9 (1.5)	0.056
Preoperative VAS cores	4 [3, 5]	4 [3, 5]	0.542
Surgery time (min)	75.62 (20.72)	80.20 (22.60)	0.270
Anesthesia time (min)	100.25(30.62)	108.45(26.42)	0.136
Blood loss (mL)	325 (112)	300 (102)	0.224
Primary outcome			
Sufentanil consumption at 48 h (ug)	132.6 (12.3)	141.0 (15.3)	0.002
Secondary outcomes			
Sufentanil consumption at 24 h (ug)	78.3 (6.1)	94.0 (10.2)	< 0.001
First standing (h)	31.77 (28.32,35.21)	30.28 (27.85,32.71)	0.511
Remedial analgesia (h)	16.89 (14.66,19.12)	10.10 (8.94,11.27)	0.004

Data shown as means (standard deviations), medians [interquartile ranges], and number of patients (%). *ASA* American Society of Anesthesiologists, *BMI* body mass index, *aCCI* age-adjusted Charlson Comorbidity Index, *VAS* visual analogue scale, *PENG* pericapsular nerve group block

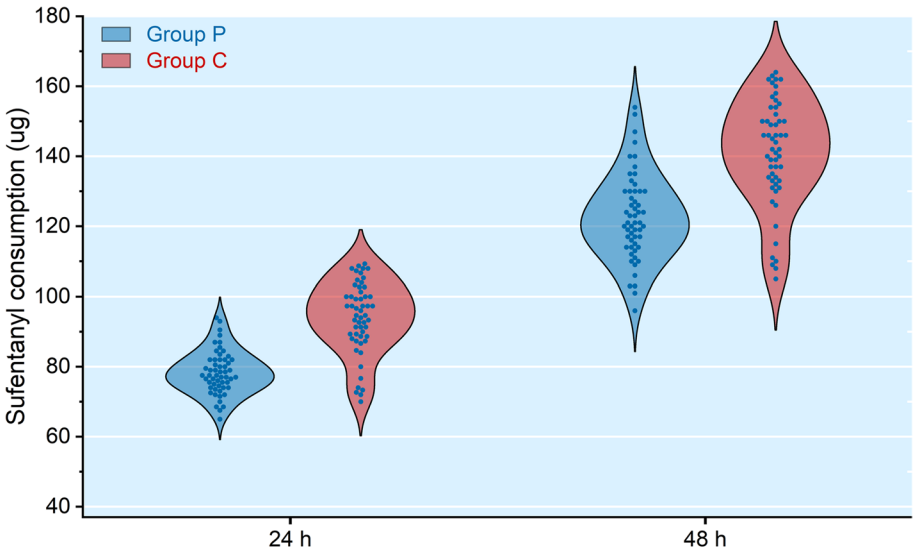

Fig. 3 Consumption of sufentanil at 24 and 48 h after surgery

Statistical difference was observed between the two groups with respect to the main effect of postoperative resting VAS scores ($P_{Group}<0.001$) and the interaction effect ($P_{time*Group}<0.001$). There was a statistically significant difference between the two groups in the resting VAS scores at the time of PACU and 6 and 12 h ($p<0.001$, 0.001, and 0.001) (Fig. 4C, E). There was a statistical difference in the main effect of

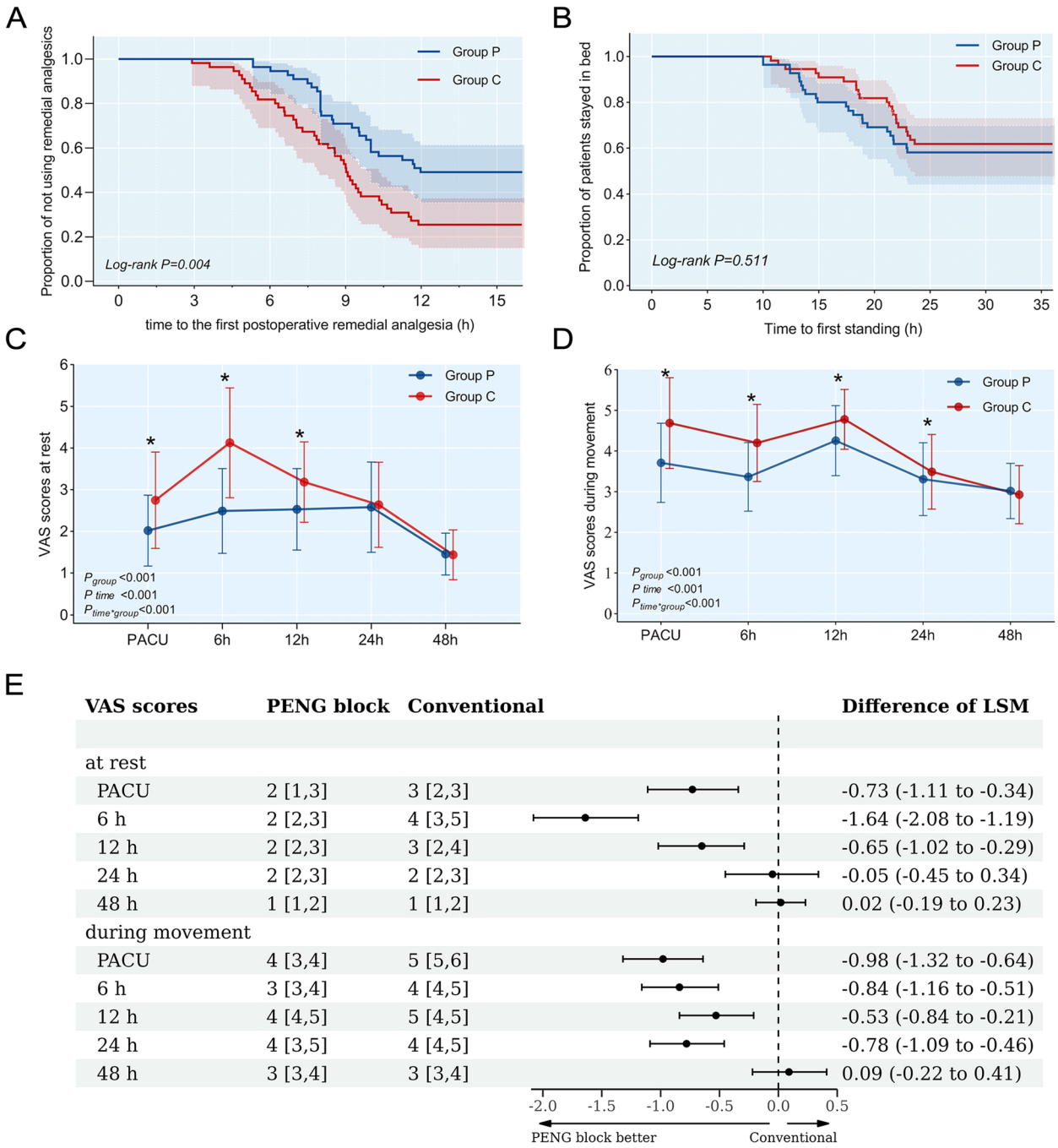

Fig. 4 Kaplan–Meier curve analysis of the time to first standing (**A**) and time to first postoperative remedial analgesia (**B**). *Visual analogue scale* pain score trajectories at rest and during movement (**C**, **D**). A forest plot of pain score over time (**E**)

postoperative VAS scores during movement between the two groups ($P_{Group} < 0.001$) and an interaction effect ($P_{time*Group} < 0.001$). There was a statistically significant difference between the two groups at the time of PACU and 6, 12, and 24 h ($P < 0.001$, 0.001, 0.001, and 0.001,) (Fig. 4D, E). The nerve block-related complications and postoperative adverse events observed are shown in Table 2.

Table 2 The adverse events observed for patients in this study

	PENG block group ($n=55$)	Conventional group ($n=55$)	*P*-value
Complications of nerve blocks			
Local anesthetic poison	0	NA	
Infection	0	NA	
Hematoma	0	NA	
Nerve injury	0	NA	
Quadriceps motor block			
No block	52 (94.5)	NA	
Paresis	3 (5.5)	NA	
Paralysis	0	NA	
Postoperative events			
Nausea or vomiting	6 (10.9)	10 (18.2)	0.28
Urinary retention	4 (7.3)	6 (10.9)	0.51
Drowsiness	2 (3.6)	4 (7.3)	0.67
Dizziness	3 (5.5)	4 (7.3)	>0.99
Constipation	3 (5.5)	6 (10.9)	0.49
Pruritus	3 (5.5)	4 (7.3)	>0.99

Data are shown either as means (standard deviations), or number of patients (%)

Discussion

The PENG block has been identified as a method of addressing acute and perioperative pain after hip fracture surgery [15, 16]. The population for this randomized controlled trial consisted of elderly patients undergoing elective PFNA under general anesthesia. There have been few studies reported on the efficacy of the PENG block for perioperative analgesia in this patient population. We found that patients who received a PENG block for PFNA had lower opioid use at 48 h postoperatively compared to the control subjects. This primary outcome was consistent with the results of three previous clinically controlled trials, either placebo-controlled or blank-controlled, conducted in recent years [17–19]. Furthermore, in the secondary observations of our study, opioid consumption was lower in the PENG block group when compared to the conventional multimodal analgesia group at 24 h postoperatively. Additionally, the median time of time to first postoperative remedial analgesia was longer in the PENG block group (16.89) compared to the conventional group (10.10). We found a clinical difference in VAS scores only during the resting state at 6 h postoperatively, suggesting that the duration of the block may be 6–12 h postoperatively. Numerous case series reports and trials have confirmed the effectiveness of the PENG block in relieving acute postoperative pain [20–22]. Pascarella et al. [17] demonstrated a reduction in the numerical rating scale (NRS) scores at 24 h postoperatively in patients undergoing postoperative total hip arthroplasty who received the PENG block, with a statistically significant difference as well as a reduced postoperative consumption of opioids.

Our study investigated the application of PENG block in elderly patients undergoing PFNA for the first time. It demonstrated that PENG block effectively reduces opioid consumption and early postoperative pain scores, thereby potentially facilitating early patient recovery and mitigating postoperative complications to a certain extent. Furthermore, our findings also revealed its efficacy in providing satisfactory analgesia for postoperative PFNA, thus expanding the applicability of PENG block. Lastly, the puncture technique and local anesthetic dosage and concentration employed in our study were deemed safe and reliable for elderly patients. Therefore, our research contributes valuable insights to current clinical investigations.

It should be noted that the PENG block only accounts for the peripheral nerves of the anterior hip capsule, and neglects analgesia of the skin incision. However, according to Nielsen et al. [23], most incisions for hip surgery are innervated by the dermal branches of the ilioinguinal and subcostal nerves, and the lateral femoral cutaneous nerve block only covers part of the surgical incision. To address this, we chose to administer ropivacaine for surgical incision infiltration anesthesia after surgery in both groups to provide analgesia for the surgical incision during the early postoperative period. This also minimizes the confounding factors affecting the assessment of analgesic efficacy for the PENG block. During the follow-up of this study, it was found that some patients in the PENG block group had a VAS score ≥ 4. The reason for this may be that the PENG block only provides analgesia to the anterior hip capsule, which, although it is the main cause of hip pain, neglects the posterior capsule. The posterior capsule of the hip joint is innervated by the hip branch of the sciatic nerve (SN), the superior gluteal nerve (SGN), and the hip branch of the femoral quadratus nerve (FQN) [8]. Some researchers have proposed combining the PENG block with either sciatic or local infiltration anesthesia in order to provide more complete analgesia of the hip capsule [24, 25].

In this study, three patients in the PENG block group experienced quadriceps paralysis. Some studies have suggested that the PENG block neither weakens the strength of the quadriceps muscle [17, 18]; nor preserves strength better than the femoral nerve [20] and suprainguinal fascia iliaca block [16]. However, other studies have indicated that the PENG block can weaken the quadriceps muscle, particularly when injected in volumes exceeding 20 mL [24, 26–28]. Cadaveric studies have also demonstrated that injecting local anesthetic volumes greater than 20 mL during the PENG

block can lead to unintended motor block by spreading between the pectineus and psoas muscles, affecting the femoral nerve [27, 29]. Mistry et al. [30] summarized the successful experience of around 200 cases of PENG block. the choice of injection site and the differences in the type, concentration and dose of local anesthetics may unintentionally affect the motor branch of the femoral nerve.

However, our study has several limitations. Firstly, the volume of 20 ml utilized in our study may be excessive for the elderly population and could potentially induce quadripleural weakness in certain patients. Secondly, our observational index for the recovery of postoperative hip function may be inappropriate. There was no statistical difference in the time to first standing between the two groups after surgery, and this was perhaps related to the surgeon's need for the patient to delay weight-bearing ambulation. Therefore, this study failed to indicate whether the PENG block promoted the recovery of hip function. Indeed, early mobilization is a complex recovery process that involves multiple psychological and physiological factors. Finally, there was no assessment of the isometric muscle strength after the peripheral blocks were performed.

Conclusions

Our findings suggest that incorporating a PENG block into a multimodal analgesia protocol, which already includes local anesthetic, PCA, and tramadol, can decrease the amount of opioids needed for elderly patients who are undergoing PFNA with general anesthesia.

Abbreviations

PENG	Pericapsular nerve group
PFNA	Proximal femoral nail anti-rotation
IFF	Intertrochanteric femur fracture
ERAS	Enhanced recovery after surgery
PNB	Peripheral nerve block
FN	Femoral nerves
ON	Obturator nerves
AON	Accessory obturator nerves
AIIS	Anterior inferior iliac spine
PACU	Post-anesthesia care unit
SPI	Surgical pleth index
PCIA	Patient-controlled intravenous analgesia
VAS	Visual analogue scale

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-024-02805-1.

Supplementary Material 1.

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Authors' contributions

Han Wu and Rui-zhi Yang: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Writing original draft. Yu Chen, Liang-Cheng Qiu, and Ting Chen: Conceptualization; Data curation; Investigation; Project administration. Xiao-Dan Wu: Conceptualization; Data curation; Funding acquisition; Project administration; Supervision; Writing - review & editing. All authors read and approved the final manuscript.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author (Xiao-Dan Wu) upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the institutional review board of Fujian Provincial Hospital (April 30, 2021; K2021-04–080) and was registered in the Chinese Clinical Trial Registry (ChiCTR2100054290) on December 13, 2021. This study followed the CONSORT guidelines and Declarations of Helsinki. Written informed consent was obtained from all participants in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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