The Prospective Randomized Controlled Study Comparing the Analgesic Effects and Quadriceps Strength between Femoral Nerve Block and PENG Block in Patients Undergoing Hip Fracture Surgery

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Abstract

Hip fracture surgery causes moderate to severe postoperative pain requiring effective analgesic management. While femoral nerve block (FNB) is commonly used for postoperative analgesia, it may compromise quadriceps strength and delay mobilization. The pericapsular nerve group (PENG) block, a novel regional technique targeting specific articular branches, is hypothesized to provide effective pain relief while preserving quadriceps function more effectively, but comparative evidence is limited. The purpose of this study was to compare the analgesic efficacy and preservation of quadriceps muscle strength between PENG block and FNB in patients undergoing hip fracture surgery. Methods: A prospective, randomized, double-blind trial was conducted with 70 patients undergoing hip fracture surgery. Participants were randomly assigned to receive either FNB or PENG block, with all patients receiving spinal anesthesia with intrathecal morphine. Primary outcomes included Tramadol consumption and time to first analgesic dose. Secondary outcomes included postoperative quadriceps strength, pain scores, and adverse effects. Median Tramadol consumption in the first 24 hr post-surgery was significantly lower in the PENG group compared to the FNB group (0 mg [IQR: 0-50] vs. 50 mg [IQR: 50-50], $p = 0.002$). Time to first Tramadol dose was significantly longer in the PENG group (20.87 ± 4.96 vs. 15.35 ± 6.37 hr, $p < 0.001$). Pain scores during 4-12 hr post-surgery were significantly lower in the PENG group (median difference 1-2 points, $p < 0.05$). Quadriceps strength at postoperative 24 hr was significantly better preserved in the PENG group, with 71.43% showing intact strength compared to 22.86% in the FNB group ($p < 0.001$). Postoperative nausea and vomiting were significantly lower in the PENG group (20% vs. 44.12%, $p = 0.04$). PENG block provides superior postoperative analgesia with better preservation of quadriceps strength compared to FNB in patients undergoing hip fracture surgery, when used as an adjunct to spinal anesthesia with intrathecal morphine. These benefits may facilitate earlier mobilization and enhanced recovery, though further studies are needed to assess the individual contributions of each analgesic modality.

Keywords: Hip fracture surgery, Pericapsular nerve group block, Femoral nerve block, Quadriceps strength, Analgesic effects

Introduction

Hip fractures are a significant cause of morbidity and mortality in elderly patients, presenting substantial challenges to public health systems (Kanis et al., 2012; Prasert et al., 2015). As the population ages, the incidence of hip fractures increases correspondingly, placing greater strain on healthcare resources (Khanthanon, 2013). Effective pain management is crucial for hip fracture rehabilitation, reducing complications and enabling early mobilization in this vulnerable patient group (Hunt et al., 2009). Furthermore, the growing demand for efficient surgery emphasizes the need to improve perioperative care that is appropriate for the needs and reduces complications in elderly patients.

Femoral nerve block (FNB) has long been a standard technique for postoperative pain management in hip fracture surgery, as its effectiveness in pain reduction has been proven (Pascarella et al., 2021; Short et al., 2018). However, FNB is associated with quadriceps muscle weakness, which often delays rehabilitation, increases the risk

of falls, leads to other complications, and prolongs functional recovery—factors crucial to outcomes in elderly patients (Zheng et al., 2022). These limitations have led to the search for alternative regional anesthesia techniques that prioritize both effective pain control and improved functional recovery.

The pericapsular nerve group (PENG) block, introduced by (Girón-Arango et al., 2018), presents an interesting alternative. This technique targets the sensory branches of the femoral nerve, obturator nerve, and accessory obturator nerve, minimizing impact on muscle function while maintaining pain control efficacy (Sardesai & Biyani, 2020). Compared to FNB, PENG block is believed to better preserve quadriceps muscle strength, enabling faster mobility and recovery (Allard et al., 2021). Reducing muscle numbness allows for faster rehabilitation, decreases complications, and reduces hospital stay duration, which is particularly important for elderly patients.

Despite potential benefits, implementing the PENG block technique faces several challenges, including technical complexity requiring advanced ultrasound skills, varying success rates due to individual anatomical differences, the extended learning curve required for physicians to develop expertise, and resource limitations in terms of specialized equipment such as ultrasound machines (Kolli et al., 2023). These challenges emphasize the need for comparative studies to validate the efficacy and safety of PENG block, particularly when considering implementation limitations due to requirements for advanced ultrasound usage and anatomical expertise.

In our study, we incorporated intrathecal morphine (ITM) as part of the spinal anesthesia protocol for all patients. ITM is known to provide effective postoperative analgesia in orthopedic procedures and is commonly used in hip fracture surgery (Mosaffa et al., 2022). While ITM offers significant pain relief, it does not typically affect quadriceps strength, making it a suitable baseline analgesic method when comparing the functional outcomes of different peripheral nerve blocks. By standardizing the use of ITM across both groups, we aimed to isolate the specific effects of PENG block versus FNB on pain control and muscle function.

This study aims to address these gaps by directly comparing PENG and FNB techniques, including postoperative analgesic consumption, quadriceps muscle strength preservation, and side effects in patients undergoing hip fracture surgery. The goal is to provide evidence supporting the role of PENG block in enhanced recovery protocols and address the limitations of current anesthetic methods. We hypothesize that PENG block will demonstrate superior efficacy in both pain relief and muscle function preservation, making it an appropriate technique for improving outcomes in hip fracture patients.

Materials and Methods

This prospective, randomized, controlled trial was conducted at Phichit Hospital, a tertiary care hospital, between May and December 2023, with approval from the Institutional Review Board (certificate of approval 0210/2566). Eligible participants included patients aged 18-75 years with ASA physical status I-III scheduled for hip fracture surgery. Patients were excluded if they had contraindications to neuraxial or regional anesthesia, coagulation disorders, local or systemic infection, central nervous system infection, known allergies to local anesthetics or opioids, communication barriers affecting pain assessment, intraoperative conversion to general anesthesia, or major surgical complications. Written informed consent was obtained from all participants.

For randomization and blinding, participants were randomly assigned (1:1) to either FNB or PENG block using computer-generated numbers in sealed opaque envelopes. The research nurse revealed block allocation immediately before the procedure for equipment preparation. While complete blinding of the proceduralist was not feasible due to anatomical differences in block placement, several measures ensured blinding, including standardized patient positioning and draping. The anesthesiologist performing the blocks was not involved in outcome assessment, and patients and outcome assessors (PACU nurses, post-op visit nurses, and ward nurses) remained blind to group allocation.

The primary outcomes of this study were: (1) total Tramadol consumption in the first 24 hr post-surgery and (2) time to first Tramadol dose. Secondary outcomes included: (1) postoperative quadriceps' strength at 24 hr, (2) pain scores at specified intervals (2, 4, 8, 12, and 24 hr postoperatively), and (3) adverse effects including nausea, vomiting, pruritus, and respiratory depression.

The intervention protocol began with standardized spinal anesthesia for all participants, using 0.5% hyperbaric bupivacaine (2.8-3.2 mL), intrathecal morphine (0.1 mg), targeting sensory level T6-T8. For the **FNB** group, under sterile conditions, a high-frequency linear ultrasound probe (6-13 MHz) was used with an inguinal region approach. The in-plane technique utilized a 22G, 80mm needle (PAJUNK), targeting below the femoral nerve through the sartorius muscle, fascia lata, and fascia iliaca. Local anesthetic consisted of 20 mL of 0.25% bupivacaine, with endpoint confirmation through real-time visualization of circumferential spread around the femoral nerve (Munirama & McLeod, 2013).

The PENG Block group procedure, also under sterile conditions, employed a curvilinear ultrasound probe (2-5 MHz), using an ASIS to AIIS scanning approach with probe rotation toward the pubic symphysis. The in-plane lateral-to-medial technique targeted the tissue plane between the psoas tendon and ilium. The same volume of local anesthetic (20 mL of 0.25% bupivacaine) was administered, with endpoint confirmation through a negative aspiration test, visualization of fluid spread between tissue planes, linear tissue plane separation, and absence of intramuscular swelling pattern. (Kolli et al., 2023)

The outcome assessment protocol encompassed multiple key parameters monitored throughout the postoperative period. Pain assessment was conducted using the Verbal Numeric Rating Scale (0-10) (VNRS) (Breivik et al., 2008; Haefeli & Elfering,2006 at specified intervals of 2, 4, 8, 12, and 24 hr by blinded ward nurses.

Quadriceps strength was assessed using the manual muscle testing technique with the knee extension test and graded according to the Oxford Scale (Clark et al., 2019), of which scores were categorized as intact (grade 5/5), reduced (grades 1-4/5), and absent (grade 0/5).

Pain management protocol included rescue analgesia with intravenous Tramadol 50 mg when VNRS scores reached or exceeded 4, administered every 6 hr as needed, supplemented by paracetamol 1g orally every 6 hr for all patients. While the PROSPECT recommendations suggest including NSAIDs or COX-2 inhibitors in the postoperative analgesic regimen, these were omitted from our protocol due to potential renal concerns in our predominantly elderly population.

Complications were monitored continuously through a standardized reporting protocol, specifically focusing on nausea, vomiting, pruritus, respiratory depression (defined as respiratory rate <8 breaths/minute or oxygen saturation

<92% on room air), hypotension (defined as >20% decrease from baseline blood pressure), and local anesthetic toxicity. Immediate physician notification was required for any serious adverse events. This systematic approach ensured consistent documentation and prompt response to any complications that might arise during the study period.

Statistical Analysis

The sample size calculation was based on a pilot study of 19 patients undergoing unilateral hip fracture surgery, which showed a mean difference in Tramadol consumption between groups of 27.78 mg (PENG: 22.22 ± 26.35 mg vs FNB: 50.00 ± 46.29 mg). With $\alpha = 0.05$ (two-sided) and power = 0.80, the required sample size was determined to be 29 patients per group. To account for a potential 20% dropout rate, we recruited 35 patients per group with 70 patients overall.

Statistical analysis was conducted using Stata 17.0. The Kolmogorov-Smirnov test was employed to assess the normality of continuous variables. Descriptive statistics were presented according to data distribution: normally distributed continuous variables were expressed as mean ± standard deviation, non-normally distributed continuous variables as median with interquartile range (IQR), and categorical variables as frequency with percentage.

For between-group comparisons, independent t-tests were used for normally distributed continuous variables, while Mann-Whitney U tests were applied for non-normally distributed continuous variables and ordinal data. Categorical variables were analyzed using chi-square tests or Fisher's exact tests as appropriate. All hypothesis tests were conducted with two-tailed analysis at a significance level of $\alpha = 0.05$. The study took an exploratory approach, avoiding adjustments for multiple comparisons to prevent increased type II errors. While missing data were reported, they were not imputed, and analysis was performed on a per-protocol basis.

Postoperative pain scores, non-normally distributed, were compared between groups using the Wilcoxon rank-sum test. Median values and interquartile ranges are reported.

Results

Each of the PENG and FNB groups had 35 patients (Fig. 1). A comparison of baseline demographics, ASA status, preoperative pain scores, and surgical characteristics showed no significant differences between the groups (Table 1).

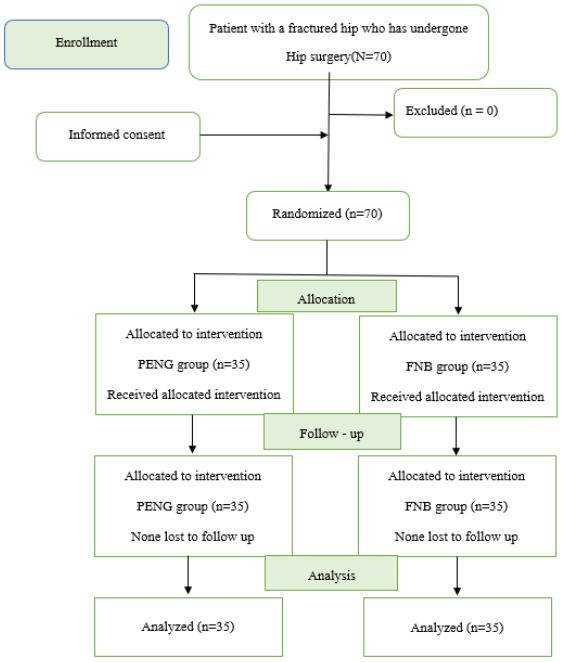

Figure 1 CONSORT diagram

Primary outcome analysis revealed significant differences in both Tramadol consumption and timing. During the first 24 hr, the PENG group required significantly less Tramadol (median 0 mg, IQR: 0–50) than the FNB group (median 50 mg, IQR: 50–50; $p = 0.002$). Additionally, the PENG group demonstrated a longer time to the first Tramadol dose (mean 20.87 ± 4.96 hr) compared to the FNB group (mean 15.35 ± 6.37 **hr**; $p < 0.001$). The number of patients receiving Tramadol was also significantly lower in the PENG block group than in the FNB group (Table 2).

Table 1 Patient Demographics and Baseline Characteristics

	PENG(N=35)	FNB(N=35)	*P*-value
Age (year) [mean ± SD]	*69.74±10.14*	*69.23±10.29*	0.83[t]
Gender, n (%)			0.60[f]
Male	*12 (34.29)*	*9(25.71)*	
Female	*23(65.71)*	*26 (74.29)*	
ASA status, n (%)			0.79[p]
I	*0 (0)*	*0 (0)*	
II	*10 (28.57)*	*11 (31.43)*	
III	*25 (71.43)*	*24 (68.57)*	
BW (kilogram) [mean ± SD]	*54.96 ± 9.66*	*53.60 ± 9.79*	0.81[t]
Operation time (min) [median (IQR)]	*115(105-130)*	*110(90-140)*	0.42[w]
Type of operation, n (%)			0.56[f]
- *PFNA*	*29(82.86)*	*26(74.29)*	
- *Bipolar hemiarthroplasty*	*6(17.14)*	*9(25.71)*	
$NRS_{Preoperation}$ *[median (IQR)]*	*3 (2,3)*	*2 (2,3)*	0.47[w]

SD = standard deviation, IQR = interquartile range, P= Pearson chi square test,t = Unpaired t test, f = Fisher Exact test, w=Wilcoxon rank sum test

Table 2 Primary outcome (Postoperative Tramadol dose, Time to first dose Tramadol)

	PENG (N=35)	FNB (N=35)	*P*-value
Postoperative Tramadol dose(milligram) [median (IQR)]	0(0,50)	50(50,50)	0.002[w]*
Time to first dose Tramadol (Hour) [mean ± SD]	20.87 ± 4.96	15.35 ± 6.37	<0.001[t]*
Patients who received Tramadol (n,%)	14(40)	27(77.1)	0.003[f]*

SD = standard deviation, IQR = interquartile range, f = Fisher Exact test, t = Unpaired t test, w=Wilcoxon rank sum test, * = statistically significant

Secondary outcomes included pain scores and quadriceps strength. Quadriceps strength assessment at 24 hr postoperatively revealed both statistically and clinically significant differences, with clinical significance defined as a difference of at least one full grade on the Oxford Scale between groups. In the PENG group, 25 patients (71.43%) maintained intact strength, with only 8 patients (22.86%) in the FNB group, which was a statistically significant difference. Conversely, reduced strength was observed in 10 patients (28.57%) in the PENG group versus 27 patients (77.14%) in the FNB group ($p < 0.001$). This substantial difference in muscle strength retention represents an important finding that may have implications for rehabilitation capacity, although our study did not directly assess functional mobility outcomes. Regarding adverse effects, the PENG group showed a significantly lower incidence of nausea and vomiting (7 patients, 20%) when compared to the FNB group (15 patients, 44.12%; $p = 0.04$). Notably, neither group reported any cases of pruritus or respiratory depression (Table 3).

Table 3 Secondary outcomes (quadriceps strength and adverse effects)

	PENG (N=35)	FNB (N=35)	*P*-value
Quadriceps strength in the recovery room (n,%)			N/A
-Intact	0(0)	0(0)	
-Reduce	0(0)	0(0)	
-Absent	35(100)	35100)	
Quadriceps strength on Day 1 (post op 24 Hr.) (n,%)			<0.001[p]*
-Intact	25(71.43)	8(22.86)	
-Reduce	10(28.57)	27(77.14)	
-Absent	0(0)	0(0)	
Complication (n,%)			
-Nausea/vomiting	7(20)	15(44.12)	0.04[f]*
-Itching	0	0	N/A
-Respiratory depression	0	0	N/A

SD = standard deviation, IQR = interquartile range, P= Pearson chi square test, t = Unpaired t test, f = Fisher Exact test, w=Wilcoxon rank sum test ,* = statistically significant

Pain assessment using VNRS showed statistically significant but clinically minimal differences between groups during the 4-12 hour postoperative period. Both groups maintained mild pain levels throughout, with no significant differences at 0, 2, and 24 hr. Notably, the greatest difference was observed between 4-8 hr postoperatively, though this represented only a 0-1 point difference on the VNRS scale (Fig. 2).

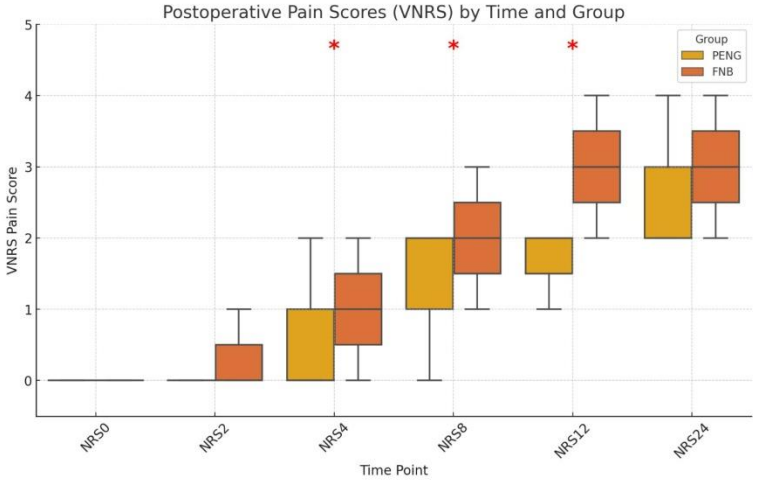

Figure 2 Postoperative pain scores in 24 hr (* = statistically significant)

Discussion

This randomized controlled trial provides evidence that the PENG block, in combination with spinal anesthesia and intrathecal morphine, offers superior postoperative pain management compared to FNB in hip fracture surgery. The primary advantages manifested as reduced analgesic consumption, improved pain scores, and enhanced quadriceps muscle strength preservation, contributing to the growing body of evidence supporting PENG block's efficacy in orthopedic surgery.

Our findings demonstrated significantly reduced Tramadol consumption in the PENG block group, corroborating previous studies (Pascarella et al., 2021; Gasanova et al., 2019; Mosaffa et al., 2022). However, these results diverge from the findings of (Lin et al., 2021), necessitating careful methodological analysis. Several key differences in protocol may explain this divergence. First, our study employed spinal anesthesia with intrathecal morphine (0.1 mg) in all patients, whereas (Lin et al., 2021). used a mix of anesthetic techniques (with spinal anesthesia in 33% of the FNB group and 43% of the PENG group, and intrathecal opioids in 17% of the PENG group). This differential use of neuraxial techniques and adjuvants could have influenced the baseline analgesic profiles in both studies. Second, our assessment methodology utilized standardized evaluation intervals (0, 2, 4, 8, 12, 24 hr) and a VNRS-based Tramadol administration protocol, which may have captured pain patterns differently. Third, there were differences in the type and concentration of local anesthetics used. Our study utilized bupivacaine 0.25% (20 mL = 50 mg) for both PENG and FNB blocks, while Lin et al. (2021). employed ropivacaine 0.75% (20 mL = 150 mg), which may have contributed to variations in block efficacy and duration due to the differing pharmacodynamic properties of these agents. Additionally, our study focused specifically on PFNA and Bipolar Hemiarthroplasty procedures, ensuring surgical homogeneity and reducing variability in postoperative pain patterns.

The superior analgesia observed in our study for both PENG and FNB groups, compared to those reported by (Lin et al., 2021), is likely attributable to our standardized use of intrathecal morphine in all patients. Intrathecal morphine is known to provide effective analgesia for up to 24 hr following administration and likely contributed

significantly to the overall pain management in both our study groups. This adjunctive analgesic measure may explain why both groups maintained relatively low pain scores throughout the assessment period.

The temporal analysis of pain scores revealed significant differences at 4, 8, and 12 hr postoperatively, favoring the PENG block group ($p < 0.05$). These findings align with recent studies, such as (Chaudhary et al., 2023; Pascarella et al., 2021), which demonstrated superior pain control in the PENG group during early postoperative periods. However, the differences in pain scores (0–1 VNRS point) require cautious interpretation, as both groups maintained VNRS scores ≤3, indicating adequate pain control. At 24 hr postoperatively, no significant differences in pain scores were observed between the groups, reflecting comparable short-term analgesic effects. Additionally, pain scores at 2 hr postoperatively did not differ significantly, likely due to the residual analgesic effects of spinal anesthesia.

Regarding functional outcomes, quadriceps strength preservation at 24 hr postoperatively aligns with previous findings (Allard et al., 2021; Lin et al., 2021). This benefit is likely attributed to the PENG block's selective targeting of sensory nerves while sparing motor fibers. Our results demonstrated a clear preservation of quadriceps strength in the PENG group, with 71.43% of patients maintaining intact strength compared to only 22.86% in the FNB group at 24 hr postoperatively. This finding is particularly important considering that by 24 hr, the effects of neuraxial anesthesia would be completely resolved, suggesting that the difference in muscle strength is attributable to the peripheral nerve block techniques rather than the residual effects of spinal anesthesia. However, future studies should validate the clinical significance of these strength improvements using functional recovery metrics, such as time to ambulation.

The safety profile analysis revealed a significantly lower incidence of nausea and vomiting ($p = 0.04$) in the PENG group, representing an important clinical advantage. This difference is likely attributable to the reduced Tramadol consumption in the PENG group, as Tramadol is known to have a considerable emetogenic potential. The FNB group required more rescue analgesia with Tramadol (77.1% of patients versus 40% in the PENG group), which correlates with their higher incidence of nausea and vomiting (44.12% versus 20%). This finding differs from (Lin et al., 2021), potentially due to several factors including our standardized antiemetic protocols, reduced systemic opioid consumption in the PENG group, and population-specific characteristics that may influence susceptibility to postoperative nausea and vomiting (PONV).

Our study has several notable strengths and limitations. The strengths include a randomized controlled design ensuring robust internal validity, standardized surgical and anesthetic protocols, comprehensive outcome assessment including both pain and functional recovery metrics, and rigorous monitoring of adverse effects.

However, several limitations must be acknowledged. First, our single-center design limits generalizability to broader populations and healthcare settings. Second, the lack of a control group receiving only intrathecal morphine without peripheral nerve blocks is a significant methodological limitation, as it prevents isolation of the specific analgesic contributions of each nerve block technique versus the baseline analgesia provided by intrathecal morphine. Third, our use of as-needed Tramadol administered every 6 hr rather than patient-controlled analgesia may have reduced the precision of our analgesic consumption measurements. Fourth, we conducted non-continuous pain assessments at predetermined intervals, which may have missed critical pain fluctuations between measurement

points. Finally, we did not collect long-term functional recovery data such as time to ambulation or rehabilitation milestones, which limits our ability to translate the observed quadriceps strength preservation into meaningful clinical outcomes.

Conclusion and Suggestions

This study demonstrates the superior efficacy of PENG block compared to FNB for postoperative pain management following hip fracture surgery. The advantages include reduced Tramadol consumption, improved early postoperative pain control, enhanced quadriceps strength preservation, and a favorable safety profile. These findings support the integration of PENG block into enhanced recovery protocols for hip fracture surgery when used as an adjunct to spinal anesthesia with intrathecal morphine.

Future research should focus on methodological refinements to overcome the limitations identified in our study, particularly the implementation of control groups receiving only intrathecal morphine to better isolate the specific contributions of peripheral nerve blocks to postoperative analgesia and functional recovery. Additionally, investigation of long-term functional outcomes would provide valuable insights into the clinical significance of the quadriceps strength preservation observed with PENG block.

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Author Contributions

Satabongkot Tangtong: Conceptualization, development or design of methodology, Investigation, Data analysis and interpretation, Manuscript writing, Manuscript review, and editing.

Usanee Panpeng: Provision of subjects or patients.

Conflict of Interests

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