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Effect of bupivacaine concentration on ultrasound-guided pericapsular group nerve block efficacy in hip surgery patients: comparative, randomized, double-blinded clinical trial

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Abstract

Background: The pericapsular nerve group (PENG) block offers effective postoperative pain relief following hip fracture surgery. This research investigated three doses of bupivacaine, all administered in the same total volume, for performing ultrasound-guided PENG blocks during hip fracture procedures.
Methods: This randomized, double-blinded clinical trial was conducted on 135 patients aged between 18 and 70 years of both sexes who underwent hip fracture surgeries. Participants were randomized into three groups (n = 45). Ultrasound-guided PENG block was applied, the groups received 20 mL of local anesthetics. The first group received 0.5% bupivacaine, the second group received 0.375% bupivacaine, and the third group received 0.25% bupivacaine. The following parameters were recorded: onset of sensory block, resting NRS after passively raising the limb by 15° half an hour post-procedure, quality of recovery score (QoR-15) at 24 h postoperative.
Results: The 0.25% bupivacaine group exhibited a longer sensory block onset than the other groups ($p \le .05$). Significant differences were demonstrated between the groups regarding the time to 1st analgesia (p = .033) and total morphine consumption (p = .025). NRS at baseline and T30 post-block did not show significant differences between the studied groups. No significant differences were detected postoperatively in rest and dynamic NRS ($p \le .05$). Patient satisfaction, QoR-15 score, and ease of spinal positioning did not differ between the groups.
Conclusion: Compared to 0.25% bupivacaine, PENG block with 0.5% and 0.375% bupivacaine provided a rapid onset sensory block, delayed first analgesic requirements, and reduced total morphine consumption after hip surgeries.
Protocol Registration: The trial was registered at the clinicaltrials.gov with study number (Trial ID: NCT05788458).

Keywords
Nerve block, bupivacaine, concentrations, pain management, hip arthroplasty, hip replacement

Introduction

Fractures in and around the hip are prevalent among individuals of all ages and frequently result in severe pain. Hip fractures are considered severe injuries, often leading to life-threatening consequences, which is why they are a common orthopedic emergency in the elderly

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population.[1] Research has demonstrated that surgical intervention within 48 h of a hip fracture can significantly reduce complications and mortality rates.[2]

Spinal anesthesia (SA) is the most commonly employed method of anesthesia for repairing these fractures.[3] The intense pain resulting from the fracture can impede the optimal positioning required for these procedures,[4] rendering access to the subarachnoid space challenging. Suboptimal postoperative analgesia may restrict limb mobility, consequently delaying recovery and increasing opioid consumption. Therefore, it is imperative to establish effective perioperative analgesia strategies that not only reduce the reliance on opioids but also mitigate their adverse effects, particularly in this patient population.[5]

Based on previous anatomical studies, it has been established that the articular branches of the femoral nerve, the obturator nerve, and the accessory obturator nerve (AON) play a crucial role in innervating the anterior hip capsule. Consequently, these nerves are identified as the primary targets for hip analgesia, and their effective blockade can be achieved through the pericapsular nerve group (PENG) technique.[6]

Yao et al. investigated the postoperative analgesic effects of varying ropivacaine concentrations in femoral nerve blocks. Their findings indicated that when ropivacaine concentrations were at or below 0.16%, there was a notable increase in pain scores and analgesic requirements compared to using ropivacaine at 0.5%.[7]

In a separate trial, peripheral nerve blocks (PNB) yielded lower postoperative pain scores, a longer duration of analgesia, and higher success rates when a higher concentration of local anesthetic was used in comparison to PNB with a lower concentration, despite utilizing the same volume of the anesthetic agent.[8] Furthermore, PNB with a higher concentration of local anesthetic and a smaller volume was more effective than PNB with a lower concentration of local anesthetic and a higher volume.[9]

This study aimed to assess the impact of three distinct concentrations and dosages of bupivacaine, administered in ultrasound-guided PENG blocks, on perioperative positioning and postoperative analgesia.

Patients and methods

This double-blinded, randomized, prospective study aimed to compare the effects of three bupivacaine concentrations, all administered in the same total volume, during ultrasound-guided PENG blocks in hip surgeries conducted under spinal anesthesia. The study was approved by our Faculty of Medicine's ethical committee (Approval ID: RC/1/3/2023) and was prospectively registered on clinicaltrials.gov (Trial ID: NCT05788458).

Between April 2023 and November 2023, the trial was conducted at our University Hospital. It involved a cohort of 135 patients, encompassing both sexes, with persistent pain, ASA grade I and II, and an age range of 18 to 70 years old. All patients underwent hip surgeries, including dynamic hip screw fixation and hemiarthroplasty, under spinal anesthesia, with an expected duration of approximately 2.5 h.

The exclusion criteria encompassed the following: refusal to participate, a history of ischemic heart disease, contraindications to spinal anesthesia (SA) or peripheral nerve blocks, ongoing treatment with opioids for persistent pain, and severe cognitive impairment. Furthermore, patients who underwent spine or hip surgery within the preceding 3 months or reported no discomfort while sitting alone (resting NRS <4) were also excluded.

Group assignment was conducted using opaque envelopes containing computer-generated random numbers. The anesthesiologist administering the block opened the envelope immediately before the surgery. The observer (another anesthesiologist) and the patients were blinded to the assigned group and the specific procedure being performed.

In the operating room, standard monitoring equipment, including electrocardiography, noninvasive blood pressure, and pulse oximetry, was applied to the patients. Baseline pain levels were assessed using a Numeric Pain Rating Scale (NRS) ranging from 0 (absence of pain) to 10 (most severe pain) during both rest and movement (passive elevation of the affected limb to 15°). The nerve blocks were administered with the patient in the supine position, and oxygen was delivered via nasal cannula. Intravenous midazolam and fentanyl were adjusted to ensure patient comfort.

Local anesthesia was introduced at the targeted site after identifying landmarks with ultrasound guidance. The area was prepared by applying 5% povidone-iodine followed by 70% ethyl alcohol and draping. Initially, a linear high-frequency ultrasound probe (7–15 MHz) (General Electric, "LOGIQ E") was placed in a transverse orientation over the anterior superior iliac spine (ASIS). Subsequently, it was adjusted to identify key landmarks, including the anterior inferior iliac spine, ilio-pubic eminence, iliopsoas muscle and tendon, femoral artery, and Pectineus muscle. The injection point was located within the musculo-fascial plane between the psoas tendon and ilio-pubic eminence.

Patients were divided into three groups for treatment. Group I, consisting of 45 patients, received 20 mL of 0.5% bupivacaine. Group II, comprising

45 patients, received 20 mL of 0.375% bupivacaine. Finally, Group III, with 45 patients, was administered 20 mL of 0.25% bupivacaine.

After administering the nerve blocks by the room anesthesiologist, patients were closely monitored for 30 min to assess for any signs of local anesthetic toxicity. Monitoring included noninvasive pulse oximetry, blood pressure measurements every 5 min, and continuous ECG monitoring. Additionally, the onset of sensory block, defined as the time elapsed from the end of the last injection to the complete disappearance of pinprick response in all nerve distributions, was carefully recorded.

Thirty minutes after administering the nerve blocks, pain levels were evaluated using the Numeric Rating Scale (NRS) at rest and during passive limb elevation. If a patient's NRS score exceeded 5, intravenous (IV) fentanyl 20 μg was administered at 5-min intervals until the NRS score reached 3. In cases where the pain score exceeded 4 at either assessment, a 25-gauge blunt needle was used to assess sensory analgesia in the thigh. If no signs of analgesia were observed in response to the pinprick, the patient was classified as a treatment failure and subsequently excluded from further participation, with permission granted for them to assume a seated position for spinal anesthesia.

On a scale ranging from 0 to 3, the ease of spinal positioning (EOSP) was assessed, with 0 indicating the patient's inability to position and 3 indicating that the patient could self-position without experiencing pain. NRS scores, the amount of administered fentanyl, and EOSP scores were recorded by an observing anesthesiologist who remained blinded to the specific regional block administered.

Spinal anesthesia (SA) was administered using a 26-gauge spinal needle, incorporating 0.4 mL of fentanyl (20 μg) and 1.8 mL of 0.5% bupivacaine (heavy), following strict aseptic protocols. Upon completing the procedure, 1 gram of intravenous paracetamol was administered as the sole intraoperative analgesic.

Patients received 1 gram of intravenous paracetamol for postoperative analgesia every 8 h. Additionally, morphine (5 mg) was provided as rescue analgesia on-demand or when the Numeric Rating Scale (NRS) score exceeded 4. All patients underwent postoperative monitoring at the following time points: 0, 2, 4, 6, 12, and 24 h postoperatively.

The primary outcomes of this study included assessing the onset of sensory block and the Numeric Rating Scale (NRS) at rest, measured half an hour after the procedure, with the limb passively raised by 15°. Secondary outcomes, observed by the observing anesthesiologist, encompassed NRS scores over the 24-h postoperative period, the quantity of morphine consumed, and the quality of recovery score (QoR-15) at the 24th-hour post-surgery, assessed using the 15-item QoR-15 questionnaire. This questionnaire evaluates five clinical aspects of health: physical comfort (five items), emotional status (four items), psychological support (two items), physical independence (two items), and pain (two items). Each question is rated on an 11-point scale, resulting in a total score ranging from 0 (indicating poor recovery) to 150 (indicating excellent recovery).

Patients' satisfaction was assessed anonymously by an independent researcher using a 5-point Likert scale, with 1 representing high dissatisfaction and 5 indicating complete satisfaction. Additionally, complications related to the block and spinal anesthesia, including nausea, vomiting, hypotension, and bradycardia, were carefully monitored.

Statistical methods

SPSS version 28 (IBM, Armonk, New York, United States) was employed for data management and statistical analysis. The normality of quantitative data was evaluated through the Shapiro–Wilk test and visual inspection of direct data representations. Depending on the normality of the data, quantitative outcomes were presented as means and standard deviations or as medians and ranges. Categorical data, on the other hand, were expressed as percentages and counts. Comparative analysis of quantitative data between the investigated groups was conducted using either one-way ANOVA or the Kruskal–Wallis test for normally and non-normally distributed quantitative variables, respectively. The Chi-square test was employed for comparing categorical data. All statistical tests were conducted as two-tailed tests, with significance levels set at a threshold of less than 0.05.

Sample size calculation

Sample size determination was performed using G*power software version 3.1.9.2, based on a prior investigation by Baskan et al. Their study observed an effect size (f) of 0.323 regarding the onset of sensory block across the three examined concentrations. Consequently, the total sample size was computed as 135 patients, with each group comprising 45 individuals. Parameters for power and alpha were set at 0.9 and 0.05, respectively.[10]

Results

General characteristics

The study included one hundred and thirty-five patients, with 45 in each group. No patient was excluded from the study (Figure 1). As shown in Table 1, no significant differences were observed between the studied groups regarding age (p = .282), sex (p = .888), body mass index (p = .210), ASA (p = .649), and ease of spinal positioning (p = .609).

Sensory block onset

Sensory block onset differed significantly between the groups (p < .001). Pairwise analysis revealed that it was significantly lower in groups I (7 ± 1 min) and II (8 ± 1 min) than in group III (11 ± 2), with no significant difference between groups I and II (Figure 2).

Numeric rating scale (NRS)

The studied groups did not significantly differ regarding preoperative NRS at baseline and T30 post-block (p = .421 and .541, respectively). Additionally, no significant differences were detected postoperatively in rest-NRS at immediate postoperative (p = .421), 2 h (p = .286), 4 h (p = .065), 6 h (p = .378), 12 h (p = .205), and 24 h (p = .612) (Table 2).

Furthermore, the studied groups did not significantly differ regarding preoperative NRS dynamic-NRS at immediate postoperative (p = .743), 2 h (p = .689), 4 h (p = .089), 6 h (p = .225), 12 h (p = .225), and 24 h (p = .367) (Table 2).

Postoperative findings

No significant differences were demonstrated between the studied groups regarding QOR-15 (p = .06), postoperative nausea and vomiting (p = .870)), and patient satisfaction (p = .397). In contrast, significant differences were demonstrated regarding time to 1st

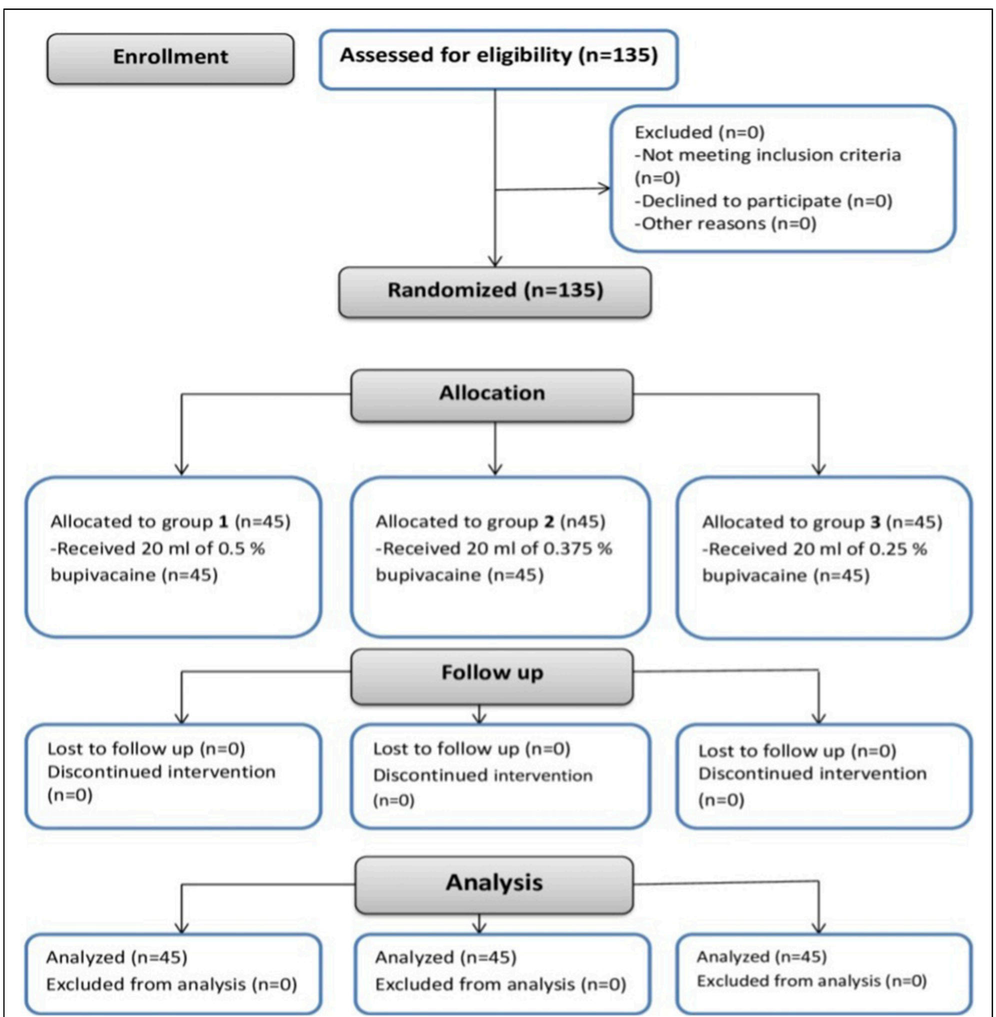

Figure 1. CONSORT flow chart.

Table 1. General characteristics of the studied groups.

		Group I (n = 45)	Group II (n = 45)	Group III (n = 45)	p-value
Age (years)	Mean ± SD	57 ± 8	59 ± 7	60 ± 6	0.282
Sex					
Males	n (%)	22 (48.9)	24 (53.3)	22 (48.9)	0.888
Females	n (%)	23 (51.1)	21 (46.7)	23 (51.1)	
Body mass index	Mean ± SD	25 ± 2	26 ± 3	26 ± 3	0.21
ASA grading					
ASA I	n (%)	13 (28.9)	15 (33.3)	11 (24.4)	0.649
ASA II	n (%)	32 (71.1)	30 (66.7)	34 (75.6)	
EOSP					
Mild discomfort	n (%)	4 (8.9)	5 (11.1)	7 (15.6)	0.609
Optimal condition	n (%)	41 (91.1)	40 (88.9)	38 (84.4)	

ASA: American Society of Anesthesiologists; EOSP: Ease of spinal positioning.

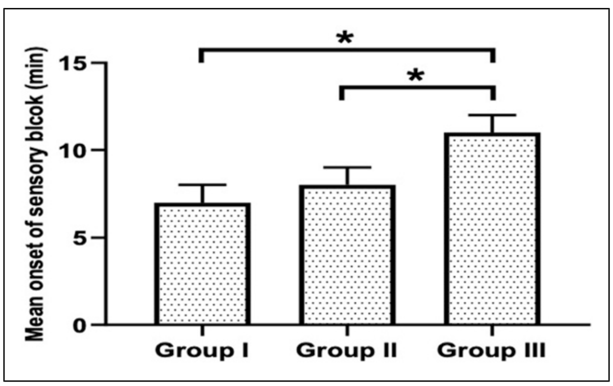

Figure 2. The onset of sensory block in the studied groups.

analgesia (p = .033) and total morphine consumption (p = .025) (Table 3, Figure 3).

Discussion

Hip surgery ranks among the most commonly performed orthopedic procedures. Typically, these surgeries are conducted under subarachnoid blocks, which can pose challenges in postoperative pain management. Effective management of postoperative pain and early healing significantly impact the functional outcomes of hip surgeries.[11]

While it is a common practice to employ opioids for pain management during hip fracture surgery, this approach may not be optimal for elderly and debilitated patients due to the potential for adverse effects such as nausea, vomiting, constipation, delirium, and respiratory depression.[12] As a result, there is a growing trend toward utilizing regional analgesic techniques for hip fracture surgery to mitigate these potential complications.[13] Regional anesthesia is increasingly recognized as a valuable pain management alternative in orthopedic procedures, either in combination with general anesthesia or as a standalone technique. Peripheral nerve blocks, for instance, can reduce the need for general anesthesia and provide effective postoperative pain relief. The pericapsular nerve group (PENG) block, in particular, offers the advantage of patient comfort in the supine position, which is especially crucial for individuals with recent hip fractures or persistent pain. Moreover, since it selectively targets the sensory articular branches, significant motor weakness is typically avoided.[14,15]

In our present study, we compared three different concentrations of bupivacaine for ultrasound-guided PENG blocks in hip surgeries, utilizing an identical total volume for each group. Notably, the group receiving 0.25% bupivacaine exhibited a significantly prolonged sensory block onset compared to the other groups ($p \leq .05$). Furthermore, this particular group demonstrated the earliest regression of sensory block and the highest requirement for analgesics.

Numerous studies have shown that manipulating the volume or concentration of local anesthetic can significantly influence the outcome of nerve blocks. For instance, investigations conducted by Smith BE et al. and Mu-iz MT et al. in the context of sciatic nerve blocks revealed shorter onset times when employing higher concentrations with lower volumes of local anesthetic, as opposed to using higher volumes with lower concentrations.[16,17]

In a study by Krenn H et al., the onset times of motor and sensory blocks during axillary plexus blockade were examined. A consistent dose of 150 mg of ropivacaine was utilized, and it was mixed with NaCl 0.9% at volumes of 30, 40, or 60 mL. The objective was to assess the impact of varying volume and concentration combinations. The results indicated that employing a higher volume with a lower concentration resulted in a quicker motor block of the axillary nerve than using a higher concentration with a lower volume.[18]

Table 2. Pre and postoperative numeric rating scale in the studied groups.

NRS		Group I (n = 45)	Group II (n = 45)	Group III (n = 45)	p-value
Preoperative					
Baseline	Median (range)	6 (4 - 8)	6 (4 - 8)	6 (5 - 7)	0.421
T30 post block	Median (range)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0.541
Postoperative					
Immediate					
At rest	Median (range)	0 (0 - 1)	0 (0 - 2)	0 (0 - 2)	0.286
Dynamic	Median (range)	0 (0 - 1)	0 (0 - 2)	1 (0 - 2)	0.743
At 2 h					
At rest	Median (range)	1 (0 - 1)	1 (0 - 2)	1 (0 - 2)	0.749
Dynamic	Median (range)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	0.689
At 4 h					
At rest	Median (range)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	0.065
Dynamic	Median (range)	1 (0 - 2)	1 (0 - 2)	1 (1 - 2)	0.089
At 6 h					
At rest	Median (range)	2 (1 - 3)	2 (1 - 3)	2 (1 - 3)	0.378
Dynamic	Median (range)	3 (2 - 4)	3 (2 - 4)	3 (3 - 4)	0.225
At 12 h					
At rest	Median (range)	3 (2 - 5)	3 (3 - 6)	3 (2 - 5)	0.205
Dynamic	Median (range)	4 (3 - 6)	4 (3 - 7)	5 (3 - 6)	0.255
At 24 h					
At rest	Median (range)	5 (4 - 6)	5 (4 - 7)	5 (3 - 6)	0.612
Dynamic	Median (range)	6 (5 - 7)	6 (5 - 8)	6 (5 - 8)	0.367

NRS: Numeric rating scale.

Table 3. Postoperative findings in the studied groups.

		Group I (n = 45)	Group II (n = 45)	Group III (n = 45)	p-value
Total morphine consumption (mg)	Median (range)	5 (5 - 5)	5 (5 - 10)	7.5 (5- 10)	0.025
Time to 1st analgesia (hour)	Mean ± SD	8.04 ± 0.9	7.86 ± 0.91	7.5 ± 0.8	0.033
PONV	n (%)	8 (17.8)	9 (20)	10 (22.2)	0.870
QOR-15	Mean ± SD	126.49 ± 2.69	125.5± 2.92	124.88 ± 3.8	0.06
Patient satisfaction					
Neutral	n (%)	0 (0)	3 (6.7)	3 (6.7)	0.397
Satisfied	n (%)	15 (33.3)	17 (37.8)	18 (40)	
Highly satisfied	n (%)	30 (66.7)	25 (55.6)	24 (53.3)	

PONV: Postoperative nausea and vomiting; QOR: Quality of recovery.

El-Sharrawy E. et al. investigated the anesthetic efficacy of different ropivacaine concentrations for inferior alveolar nerve blocks. They indicated that ropivacaine at concentrations of 0.5% and 0.75% proved to be effective local anesthetics for inferior nerve blocks, offering rapid onset and prolonged action.[8]

Numerous studies have consistently demonstrated that increasing the concentration of local anesthetic leads to reduced block onset time and improved quality of both motor and sensory blocks.[10] Nevertheless, when volume remains comparable while concentrations vary, it can notably impact the block's quality. Our results align with this understanding, as we observed that reducing the bupivacaine concentration from 0.5% to 0.375% and subsequently to 0.25% led to a significant delay in sensory block onset and a shortened duration of the block, consequently resulting in earlier postoperative analgesic requirements.

Our findings showed no significant differences among the studied groups regarding Numeric Rating Scale (NRS). Hao Li et al. evaluated the impact of epidural analgesia with varying concentrations of bupivacaine and fentanyl on postoperative pain in thoracic surgery patients. They concluded that postoperative pain did not exhibit significant differences between the groups. Specifically, when comparing the four groups

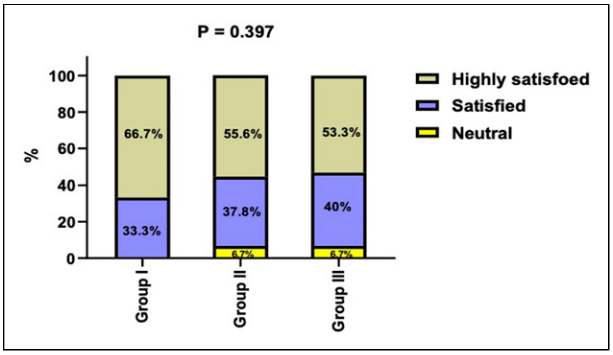

Figure 3. Patient satisfaction in the studied groups.

four hours after surgery, the Visual Analog Scale (VAS) in the fentanyl group was significantly lower than in the other three groups ($p < .05$). However, no significant differences were noted between the four groups at 8, 12, 24, and 48 h postoperatively ($p > .05$).[19]

Our findings align with Arissara et al., who assessed femoral nerve block using 0.25% or 0.5% bupivacaine for analgesia after arthroscopic anterior cruciate ligament reconstruction. They observed no significant difference in the Numeric Rating Scale (NRS) between the two groups, except at 18 h.[20] Additionally, these results are consistent with Giorgio et al., who investigated femoral nerve blockade for knee arthroscopy using different local anesthetic concentrations in pediatric patients. Their study revealed that pain scores did not differ significantly between the various local anesthetic groups.[21]

On the contrary, using varying bupivacaine concentrations, Altiparmak et al. compared the analgesic effect of erector spinae plane block after mastectomy. Interestingly, their findings differed from our observations. They reported that the group with a higher bupivacaine concentration exhibited a significantly lower Numeric Rating Scale (NRS) at all time points.[22]

Regarding ease of spinal positioning, QR15 scores, patient satisfaction, and postoperative nausea and vomiting, our study revealed no significant differences among the three groups. These results align with Xie et al., who investigated the effect of high and low concentrations of bupivacaine in total knee arthroplasty and indicated that all groups exhibited high overall satisfaction levels.[23]

Currently, the medical literature lacks definitive evidence regarding the long-term outcomes of PENG block in hip surgery. It remains essential for surgeons and anesthesiologists to ensure that patients are adequately informed about both the potential risks and benefits associated with various analgesic treatments following hip surgery. As our understanding of pain mechanisms continues to evolve, our pursuit of the most effective methods to alleviate patient pain and enhance surgical outcomes must persist.

In the current study, we employed three different bupivacaine concentrations while maintaining a consistent volume, as is typically practiced. However, it is essential to note that without identifying the minimum effective bupivacaine concentration, it remains challenging to precisely determine both the maximum and minimum durations of the block.

Conclusion

Compared to the 0.25% bupivacaine, PENG block with 0.5% and 0.375% bupivacaine provided rapid sensory block onset, prolonged time to first analgesic, and lower narcotic need following hip surgeries. The three concentrations showed similar effects regarding rest and dynamic NRS, ease of spinal positioning, QR15 score, patient satisfaction, and postoperative nausea and vomiting.

Author contributions

FAA and MAE: Concepts and Design. FAA: Definition of intellectual content. FAA and MAE: Literature search and Clinical studies. MAE: Data acquisition. FAA and MAE: Data analysis. FAA: Statistical analysis. FAA and MAE: Manuscript preparation and Manuscript editing and Manuscript review.

Declaration of conflicting interests

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IRB Statement

Benha Faculty of Medicine's ethical committee approval was obtained under the number (Approval ID: RC/1/3/2023) and written informed consents were collected from patients. We hereby transfer, assign, or otherwise convey all copyright ownership, including any rights incidental thereto, exclusively to the journal if such work is published.

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