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Pericapsular Nerve Group Block with Periarticular Injection for Pain Management after Total Hip Arthroplasty: A Randomized Controlled Trial

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Purpose: The purpose of this study was to compare the effectiveness of pericapsular nerve group (PENG) block with periarticular multimodal drug injection (PMDI) on postoperative pain management and surgical outcomes in patients who underwent total hip arthroplasty (THA). We hypothesized that PENG block with PMDI would exhibit superior effects on postoperative pain control after THA compared to PMDI alone.

Materials and Methods: From April 2022 to February 2023, 58 patients who underwent THA were randomly assigned into two groups: PENG block with PMDI group (n=29) and PMDI-only group (n=29). Primary outcomes were postoperative numeric rating scale (NRS) at rest and during activity at 6, 24, and 48 hours postoperatively. Secondary outcomes were postoperative complications (nausea and vomiting), Richards-Campbell Sleep Questionnaire (RCSQ) score, length of hospital stay, Western Ontario and McMaster Universities Osteoarthritis (WOMAC) index, Harris Hip Score (HHS), and total morphine usage after surgery.

Results: There was no significant difference in postoperative pain for either resting NRS or active NRS. Postoperative nausea and vomiting, RCSQ score, length of hospital stay, WOMAC index, HHS, and total morphine usage exhibited no significant differences between the two groups.

Conclusion: Both groups showed no significant differences in postoperative pain and clinical outcomes, indicating that the addition of PENG block to PMDI does not improve pain management after applying the posterolateral approach of THA. PMDI alone during THA would be an efficient, fast, and safe method for managing postoperative pain. This article was registered with ClinicalTrials.gov (Gov ID: NCT05320913).

Key Words: Pericapsular nerve group block, PENG block, periarticular multimodal drug injection, PMDI, total hip arthroplasty

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INTRODUCTION

Total hip arthroplasty (THA) is one of the most frequent procedures in orthopedic surgery. According to Statistics Korea 2021, approximately 30000 cases of hip reconstruction surgery including THA were performed, and the number has been increasing every year.[1] Pain control after THA helps facilitate early ambulation and patient satisfaction. However, there is no gold standard for pain control after THA.[2,3] The main objective for pain management after orthopedic surgery is fast recovery and rehabilitation with sufficient pain control and sufficient muscle power.[4] The regional analgesia technique is an effective method for reducing pain and opioid consumption in multimodal analgesia.[5] However, due to the complex nerve distribution in the hip joint, there is no consensus on an ideal pain block for postoperative pain after THA.[6]

The femoral nerve (FN), obturator nerve (ON), and sciatic nerve are distributed in the hip joint. The anterior capsule of the joint is mainly controlled by the joint branches of the FN, ON, and accessory obturator nerve (AON). The posterior aspect of the joint is supported by the superior gluteal nerve, the inferior gluteal nerve of the sacral plexus, and the nerve that branches directly from the sacral plexus to the quadratus femoris (Fig. 1).[7] Moreover, it is necessary to block the lateral femoral cutaneous nerve for pain management when approaching the hip joint on the lateral side of the hip during surgery.[8]

Girón-Arango, et al.[9] introduced a new technique [pericapsular nerve group (PENG) block] for selective blockade of the articular branches from the femoral, AON, and ONs. This PENG block has demonstrated sufficient analgesic effects with reduced pain scores and no quadriceps weakness in patients with hip fracture.[9,10] PENG block also exhibited remarkable benefits for immediate postoperative pain control after primary THA.[11] However, this technique only included the anterior capsule of the hip joint, with no posterior capsule involvement.

Periarticular multimodal drug injection (PMDI) during total knee arthroplasty (TKA) and THA was developed by Kerr and Kohan[12] to avoid the potential complications of traditional techniques. They describe the injection into the tissues around the rim of the acetabulum, focusing on the joint capsule if it remains, and around the exposed gluteal and adductor muscles. An additional injection is administered into the external rotators, gluteus tendon, and iliotibial band. PMDI during THA appears to be an efficient and safe adjunct for pain control.[13-16] Moreover, this method can also involve the posterior capsule of the hip joint with direct injection.

Although many studies have focused on postoperative pain control after THA using various methods, no study has analyzed whether PENG block with PMDI can have synergistic effect on postoperative pain control after THA. Therefore, the current study hypothesized that PENG block with PMDI would significantly alleviate pain after THA and improve early functional outcomes compared to PMDI alone. This study aimed to compare the results of PENG block with PMDI versus PMDI alone in terms of the effectiveness of pain management, difference in total opioid use, functional outcomes, and postoperative complications.

MATERIALS AND METHODS

Data collection

This study was approved by an independent Institutional Review Board (#4-2021-0725) and was also registered with ClinicalTrials.gov (Gov ID : NCT05320913). A total of 58 patients with an American Society of Anesthesiologists (ASA) physical status of class I–III who underwent primary THA from 2022 to 2023 at a single hospital were included. Patients with inflammatory hip arthritis, including rheumatoid arthritis, hip-joint infection, revision surgery, severe instability, anatomical defor-

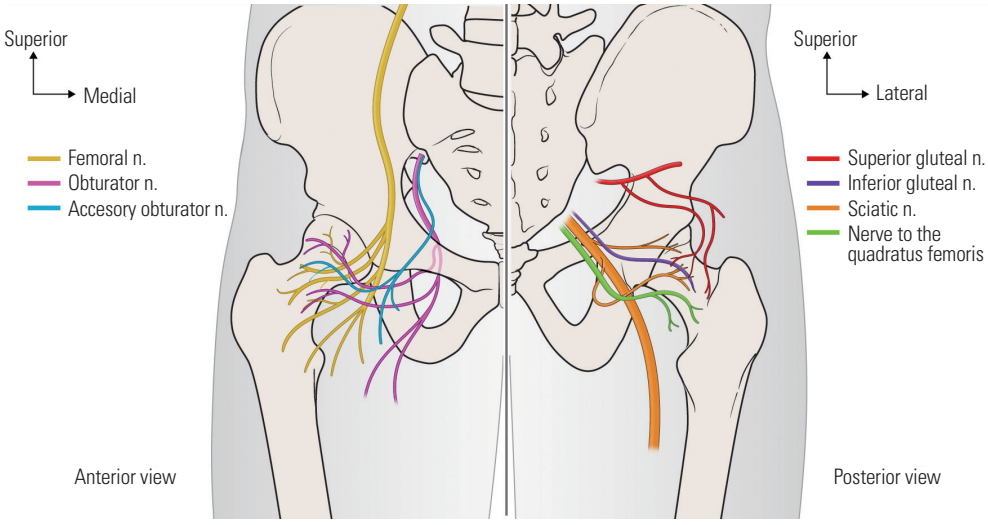

Fig. 1. Nerve innervation of hip joint (anterior and posterior).

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mity, or bone defects, were excluded. The 58 patients were divided into two groups: 29 patients who received PENG block with PMDI (PENG with PMDI group) and 29 patients who received PMDI alone (PMDI group). Random allocation was performed using a random number table.

All THA surgeries were performed by one experienced orthopedic surgeon at a tertiary teaching hospital. All cases were performed using a posterolateral hip approach in the lateral position, along with repair of the short rotator muscle. Cementless press-fit stems were used in all cases. After insertion of the cup and stem, PMDI was performed on all patients. The injection contained 150 mg of ropivacaine, 30 mg of ketorolac, and 0.3 mg of epinephrine. These were mixed with sterile normal saline solution to achieve a combined volume of 50 mL in the operating room. In the PMDI group, a total volume of 50 mL of the mixture was injected as follows: 20 mL through an intracapsular method (labral base, anterior hip capsule, and ligamentum teres), 15 mL into the tensor fascia lata and subcutaneous tissue, and 15 mL into the abductors and short external rotator muscles. In the PENG with PMDI group, a total volume of 40 mL of the mixture was injected as follows: 20 mL through an intracapsular method (labral base, anterior hip capsule, and ligamentum teres), 10 mL into the tensor fascia lata and subcutaneous tissue, and 10 mL into the abductors and short external rotator muscles. In the PENG with PMDI group, PENG block was performed after surgery by injecting 20 mL of a solution containing 40 mg of 0.2% ropivacaine with epinephrine 1:200000 between the psoas tendon and pubic ramus, under ultrasound guidance.[10]

All patients received standardized general anesthesia. In the ward, all patients received celecoxib (200 mg) orally, followed by acetaminophen (1 g) intravenously every 12 hours.

All patients participated in postoperative exercises under the same rehabilitation protocol. Bedside exercises, including ankle pumps, quadricep stretches, and leg raising exercises, were performed 0–6 hours after surgery. Standing and walker ambulation was permitted on postoperative day 1 under the same rehabilitation protocol.

Outcome measurements

The postoperative numeric rating scale (NRS, 0–10 with 0="no pain" and 10="worst possible pain") was evaluated as the primary outcome. NRS was assessed at rest at 1, 6, 24, and 48 hours postoperatively and during activity (6 hours: during 45° passive hip flexion, 24 and 48 hours: ambulation) at 6, 24, and 48 hours postoperatively. Secondary outcomes were the Richards-Campbell Sleep Questionnaire (RCSQ),[17] total morphine use after surgery (calculated as oral morphine equivalents),[18] hospital stay length, and postoperative functional outcome scores [Western Ontario and McMaster Universities Osteoarthritis (WOMAC),[19] Harris Hip Score (HHS)[20]] assessed preoperatively and at 3 and 6 months postoperatively. The RCSQ is a simple five-item NRS validated for measuring sleep quality.[17]

Sample size

The sample size was calculated based on a paired t-test, expecting standard deviations of 1.7 and 2.1 for the NRS scores for PENG and PMDI, respectively.[21,22] To obtain a power of 0.80 (1-β) with a significance level (α) of 0.05, the calculated sample size was 27 cases per group.[23,24] Considering a dropout rate of 10%, the target sample size was 29 cases per group. No patients were excluded, resulting in a final total of 58 patients.

Statistical analysis

Continuous data are shown as the mean±standard deviation. By using the Kolmogorov–Smirnov test and Shapiro–Wilk test, parametricity was decided. Parametric continuous variables were analyzed by using the independent t-test. Non-parametric continuous variables were analyzed by using the Mann–Whitney U test. Categorical data are shown as count (%). Comparisons between groups were done by using either Fisher's exact test or the chi-square test. A multivariable linear mixed model was used to evaluate the repeatedly measured NRS with adjustments for age, sex, body mass index (BMI), and ASA score. A *p*-value for group-by-time interaction effect was calculated. The *p*-values from the linear mixed model were adjusted using Bonferroni correction for each time point. Data analyses were conducted using R, version 3.6.0 (The R Foundation for Statistical Computing, Vienna, Austria), and *p*-values<0.05 were considered statistically significant.

RESULTS

Baseline characteristics

Patient baseline characteristics, including age, sex, BMI, and ASA class, were compared between the two groups (Table 1). The average age was 58.83 years in the PENG with PMDI group and 61.83 years in the PMDI only group. There were patients who were diagnosed with osteonecrosis of the femoral head and decided to undergo surgery at a young age. ASA class I was assigned to 6 patients, while classes II and III involved 40 patients and 10 patients, respectively. There was no significant difference between the groups in terms of demographic data.

Primary outcome

There was no significant difference between the two groups for preoperative and postoperative pain at rest (Table 2). The estimated mean in the PMDI group was higher at 6 hours and 48 hours. The mean profile plot for the data in Table 2 is presented in Fig. 2.

There was no significant difference between the two groups for preoperative and postoperative pain at activity (Table 3). The estimated mean was lower at 6 and 48 hours in the PENG with PMDI group. The mean profile plot for the data in Table 3 is presented in Fig. 3.

Secondary outcome

There was no significant difference between the two groups for postoperative nausea and vomiting (PONV), RCSQ, total opioid use, length of hospital stay, WOMAC score, and HHS score (Table 4). Among the 58 patients, 48.28% experienced PONV, which is a common complication after surgery. Total opioid use was highest at 24 hours in both groups, followed by 6 hours, 48 hours, and 1 hour. WOMAC score was lower after THA in both groups, while HHS score increased.

Table 1. Demographic Data of the Two Groups

	Total (n=58)	PENG with PMDI (n=29)	PMDI only (n=29)	*p* value
Age (yr)	60.33±15.55	58.83±16.53	61.83±14.63	0.467
Sex				>0.999
Female	36 (62.07)	18 (62.07)	18 (62.07)	
Male	22 (37.93)	11 (37.93)	11 (37.93)	
Height (cm)	161.35±8.99	160.26±7.69	162.43±10.15	0.362
Weight (kg)	67.86±12.41	65.78±12.48	69.95±12.19	0.203
BMI (kg/m^2)	26.03±3.89	25.51±3.66	26.56±4.09	0.308
ASA (I/II/III)	7/40/11	4/21/4	3/19/7	0.109

PENG, pericapsular nerve group; PMDI, periarticular multimodal drug injection; BMI, body mass index; ASA, American Society of Anesthesiologists.
Data are presented as mean±standard deviation or n (%).

Table 2. Preoperative and Postoperative Pain at Rest

Time	PENG with PMDI		PMDI only		Raw *p* value	Adjusted *p* value
	Estimated mean*	SE*	Estimated mean*	SE*		
Pre op rest	2.5757	0.2986	3.1619	0.3147	0.155	0.774
Post op rest 1 hour	3.3343	0.4017	3.1964	0.4138	0.805	>0.999
Post op rest 6 hours	3.7136	0.4183	3.7481	0.4300	0.953	>0.999
Post op rest 24 hours	4.2998	0.4863	4.0929	0.4964	0.762	>0.999
Post op rest 48 hours	3.4722	0.3994	3.7481	0.4116	0.620	>0.999

PENG, pericapsular nerve group; PMDI, periarticular multimodal drug injection; SE, standard error; BMI, body mass index; ASA, American Society of Anesthesiologists.
p-value was determined for the group by the time interaction effect. Adjusted *p*-values were obtained by Bonferroni correction.
*The mean and SE were estimated using the linear mixed model with adjustments for age, sex, BMI, and ASA score.

DISCUSSION

This was a single-center, randomized control trial that focused on the analgesic effects and early outcomes of PENG block with PMDI.

The most important finding of this study was that the two groups exhibited no significant difference in postoperative pain. In the PENG with PMDI group, the total use of ropivacaine was 160 mg (40 mg for the PENG block, 120 mg for the PMDI). In the PMDI group, the total use of ropivacaine was 150 mg for PMDI only. Using less ropivacaine, the analgesic effect was similar between the two groups, indicating that PMDI could be an effective method for pain control after THA.

After PMDI was introduced by Kerr and Kohan in 2008,[12] several studies have focused on the effectiveness of PMDI.[13-16,25] Kerr and Kohan[12] not only performed local infiltration analgesia, but also placed catheters during the first postoperative days to gain prolonged local infusion analgesia. However, Specht, et al.[26] determined that there is no evidence of clinically important effects of local infusion analgesia. Our study performed only local infiltration analgesia in the intraoperative field, which can provide sufficient pain management after THA. There is clinical evidence that infiltration and instillation with local analgesia at operative sites can improve postoperative analgesia and reduce opioid consumption.[11,27-30] Thus, PMDI could provide

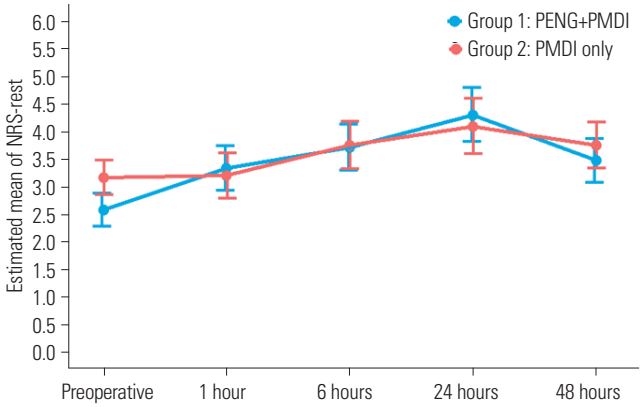

Fig. 2. Postoperative pain score at rest (pre, 1, 6, 24, and 48 hours). PENG, pericapsular nerve group; PMDI, periarticular multimodal drug injection; NRS, numeric rating scale.

Table 3. Preoperative and Postoperative Pain at Activity

Time	PENG with PMDI		PMDI only		Raw *p* value	Adjusted *p* value
	Estimated mean*	SE*	Estimated mean*	SE*		
Pre op activity	4.2323	0.3523	5.0173	0.3749	0.105	0.418
Post op activity 6 hours	4.6806	0.4143	5.2932	0.4336	0.285	>0.999
Post op activity 24 hours	5.6461	0.4457	5.5345	0.4638	0.856	>0.999
Post op activity 48 hours	4.4737	0.4399	4.7414	0.4581	0.659	>0.999

PENG, pericapsular nerve group; PMDI, periarticular multimodal drug injection; SE, standard error; BMI, body mass index; ASA, American Society of Anesthesiologists.
p-value was determined for the group by the time interaction effect. Adjusted *p*-values were obtained by Bonferroni correction.
*The mean and SE were estimated using the linear mixed model with adjustments for age, sex, BMI, and ASA score.

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sufficient postoperative analgesia effect after THA.

The PENG block, which was introduced by Girón-Arango, et al. in 2018,[9] is a recently developed pain block method used in hip surgeries. The advantage of PENG block is that it could be motor-sparing by targeting only the sensory branches of the FN and AON.[9] Although there is a concern for quadriceps weakness in some cases,[31] there was no adverse effect of needle placement using PENG block in this study. In a meta-analysis, Wang, et al.[7] determined that PENG block is effective and safe for postoperative analgesia following hip surgery. Therefore, PENG block with PMDI could provide a synergistic effect on postoperative pain management after THA. However, the result of this study demonstrated no clinical differences with the use of more total ropivacaine (160 mg) since PENG block and PMDI involved similar areas. Although PMDI could cover both anterior and posterior aspects of hip joints, the nociceptors of the hip joint are mainly concentrated at the labral base and the ligamentum teres.[32] This is likely why the two pain control methods exhibited no significant difference. Second, we used only 150 mg or 160 mg of ropivacaine, which is almost half the amount of dose suggested by Kerr and Kohan.[12] Thus, PENG block did not demonstrate as great an analgesic effect as we expected. Moreover, PMDI can be performed in the surgical field in about 1 minute, whereas PENG block requires at least 30 minutes after surgery. That is, PMDI can reduce the time interval after surgery to prepare for next surgery in practice, which could increase the efficiency of hospital schedule. During the posterolateral approach of THA, the anterior portion of the hip joint is not incised or repaired, and only the labrum base is removed. In the direct anterior approach of THA, the results can be different. In the direct anterior approach of THA, PENG block with PMDI could provide a synergistic effect on postoperative pain management after THA.

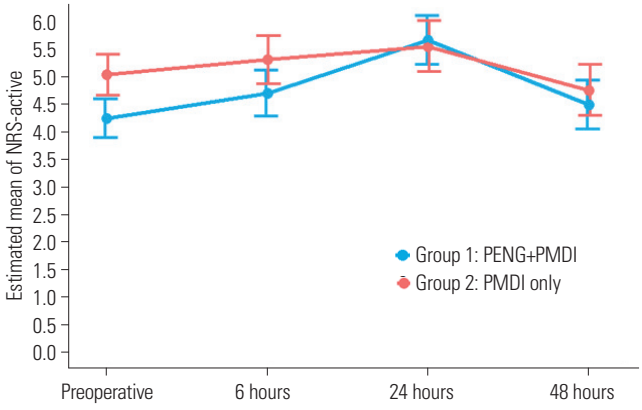

Fig. 3. Postoperative pain score at activity (pre, 6, 24, and 48 hours). PENG, pericapsular nerve group; PMDI, periarticular multimodal drug injection; NRS, numeric rating scale.

Secondary outcomes (PONV, RCSQ, total opioid use, WOMAC, and HHS) exhibited no significant difference between groups. According to PONV, RCSQ, and total opioid use, the groups showed no significant differences in postoperative pain at rest and activity. Total opioid was used more often when the estimated mean of postoperative pain at rest and activity was high (at postoperative 24 hours). This is because ambulation after THA typically occurs 24 hours after surgery, when patients are more likely to experience pain. WOMAC and HHS scores were calculated after 3 and 6 months with no noticeable effects of pain control, indicating no significant difference between the two groups. As expected, in both groups, WOMAC

Table 4. PONV, RCSQ, Total Opioid Use, Length of Hospital Stay, WOMAC Score, and HHS Score

	Total (n=58)	PENG with PMDI (n=29)	PMDI only (n=29)	*p* value
PONV	28 (48.28)	12 (41.38)	16 (55.17)	0.431
RCSQ	199.31±52.78	212.07±62.76	186.55±37.35	0.066
Total opioid use	13.62±16.19	11.03±15.43	16.21±16.78	0.227
Postoperative 1 hour	2.07±4.09	1.72±3.84	2.41±4.35	0.525
Postoperative 6 hours	3.97±4.93	3.45±4.84	4.48±5.06	0.430
Postoperative 24 hours	4.66±9.03	3.45±10.10	5.86±7.80	0.313
Postoperative 48 hours	2.93±4.96	2.41±4.35	3.45±5.53	0.432
Length of hospital stay	5.60±1.78	5.41±1.05	5.79±2.29	0.423
WOMAC				
Preoperative	55.50±19.16	56.83±22.20	54.36±16.45	0.647
Postoperative 3 months	20.32±11.40	22.91±12.83	18.65±10.42	0.343
Postoperative 6 months	17.62±13.50	19.43±14.02	15.50±13.84	0.622
HHS				
Preoperative	46.60±20.50	47.88±22.78	45.45±18.59	0.671
Postoperative 3 months	83.31±17.53	83.63±8.97	83.12±21.41	0.929
Postoperative 6 months	75.45±34.26	64.00±44.34	88.81±7.76	0.193

PENG, pericapsular nerve group; PMDI, periarticular multimodal drug injection; PONV, postoperative nausea and vomiting; RCSQ, Richards-Campbell Sleep Questionnaire; WOMAC, Western Ontario and McMaster Universities Osteoarthritis; HHS, Harris Hip Score.
Data are presented as mean±standard deviation or n (%). *p*-value was determined for the group by the time interaction effect.

and HHS scores were improved after surgery.

THA can improve the quality of life for patients who suffer from osteoarthritis, osteonecrosis of the femoral head, and hip dysplasia. However, after THA, postoperative pain was so severe that several patients who exhibited disease in both hips discontinued treatment after unilateral THA, despite remaining disease in the other hip. Therefore, it is essential for surgeons to effectively manage postoperative pain for every patient. In our hospital, nerve block or PMDI is routinely performed on patients who undergo TKA or THA. As a result, ambulation is achieved within 1 day and home discharge within 2 days after surgery.

This study had several limitations. First, the total use of ropivacaine differed between the two groups. For efficiency, the cocktail of PMDI injections was created for all patients with the same recipe as the protocol. The difference was in the amount the surgeon used in the operative field, which was convenient for the procedure. If the total volume of ropivacaine had been same, the result might have been more reliable. However, the difference in amount was only 10 mg, within the error range. Second, the total use of ropivacaine was almost half the amount suggested by Kerr and Kohan.[12] However, guidelines suggested that the maximum single dose with vasoconstrictor (mg/kg) is 3–4 mg/kg and should not exceed 255 mg per dose. Considering old age and ASA III class patients, the amount should be less and was determined to be 150 mg or 160 mg. In addition, several studies have used ropivacaine 150 mg or 200 mg.[15,26] Third, this study was designed to examine the posterolateral approach of THA, and PENG block could have minimal effect, as it is an anterior-based block. Further studies using both anterior approach and posterior approach of THA are warranted. Finally, there was no control group, such as one without blockade, in this study. Although a control group was absent, the beneficial effects of both PENG block and PMDI on pain management after THA have already been proven in many studies. Therefore, the conclusion of this study remains meaningful.

In conclusion, both groups exhibited no significant differences in postoperative pain and clinical outcomes, indicating that the addition of PENG block to PMDI does not improve pain management after applying the posterolateral approach of THA. PMDI alone during the posterolateral approach of THA would be an efficient, fast, and safe method for managing postoperative pain.

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AUTHOR CONTRIBUTIONS

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