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Ultrasound-guided pericapsular nerve group block versus fascia iliac compartment block for pain control in lower limb orthopedic surgery: A meta-analysis from randomized controlled trials

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Abstract: *Ultrasound-guided pericapsular nerve group block (PENG) and fascia iliac compartment block (FICB) are alternative methods of pain relief during lower limb orthopedic surgery. However, the efficacy and safety of PENG compared with FICB have not been fully established.We comprehensively searched randomized controlled trials (RCTs) about comparing PENG with FICB for patients with lower limb orthopedic surgery through the databases of Pubmed, Embase, Cochrane Library, CNKI and Wanfang database with no limitation of language from their inception date to December 2022. Two reviewers were independently involved in the process of data extraction. The main outcome measures were pain scores in resting state and exercise state at different time points. Secondary outcome indexes were the first analgesia time, intraoperative remfentanil consumption, fentanyl consumption at 24 hours after surgery, morphine consumption at 24 hours after surgery, satisfaction score for postoperative analgesia, quadriceps muscle strength at 6 and 24 hours after surgery, incidence of adverse reactions such as nausea and vomiting. The Rev Man 5.3 software was used for meta-analysis of the data.Finally, a total of 8 RCTs with 210 patients in PENG group and 201 patients in FICB group were included in this meta-analysis. Pooled analysis indicated that there were no significant differences between the two groups in resting state and exercise state pain scores before nerve block and postoperative incidence of nausea and vomiting (P>0.05). Compared with FICB, pain scores at 10nim, 20min and 30min after nerve block, at 6h, 12h, 24h and 48h after surgery at resting state and exercise state, intraoperative remifentanil consumption, total sufentanil consumption and morphine consumption at 24h after surgery were significantly reduced in PENG group (P<0.05). In addition, compared with FICB group, the first postoperative analgesia time, postoperative analgesia satisfaction score, and quadriceps muscle strength 6h and 24h after surgery were significantly improved in PENG group (P<0.05) .Existing clinical evidence shows that compared with FICB , ultrasus-guided PENG has better analgesic effect in lower limb orthopedic surgery, patients need less intraoperative and postoperative opioid analgesic drugs, the duration of analgesia is longer, the effect on postoperative lower limb muscle strength of patients is less, and the occurrence of adverse reactions of nausea and vomiting is not increased.*

Keywords: *ultrasound; pericapsular nerve group block; fascia iliac compartment block; pain control; lower limb orthopedic surgery; meta-analysis*

1. Introduction

Lower limb orthopedic surgery is common in clinic, which can effectively restore the lower extremity function and promote the early recovery of the body. However, there are more traumatic operations such as soft tissue dissection in lower limb orthopedic surgery, which can easily lead to the release of a large number of inflammatory mediators and activation of peripheral nociceptors, thus producing severe pain[1]. Severe pain seriously interferes with patients' postoperative recovery and exercise, and with the extension of time, postoperative acute pain will gradually develop into chronic pain, causing more serious impact on patients' prognosis and quality of life[2]. Therefore, it is particularly critical to adopt reasonable and effective analgesic measures for perioperative patients. Conventional analgesia is mainly intravenous analgesia. Although this method can relieve patients' pain, the incidence of complications

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such as respiratory depression, nausea, vomiting and dizziness after analgesia is relatively high, so the application of this method has certain limitations[3]. In recent years, with the mature application of ultrasound technology, FICB has been promoted as a valuable technique for regional anesthesia and analgesia in lower limb orthopedic surgery[4]. However, FICB was found to decrease quadriceps muscle strength, and the duration of postoperative analgesia was shorter[5-6]. Recently, PENG has gradually become an emerging analgesic method because it can block the obturator nerve, accessory obturator nerve and femoral nerve which innervate the anterior capsule of hip joint and produce good analgesic effect without affecting the motor nerve[7]. Several studies[8-15] have been conducted in recent years on the effects of PENG and FICB, perioperatively. Although some conclusions have been drawn, whether PENG would be equivalent to FICB for analgesia in lower limb orthopedic surgery has not been studied through meta-analysis. Therefore, we performed the present meta-analysis to compare the effects of PENG and FICB on the reduction of pain and side effects from randomized controlled trials and to provide a reference for clinicians to select appropriate regional nerve block methods during lower limb orthopedic surgery.

2. Methods

This meta-analysis was reported in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines[16]. This was a report on the previous published studies, thus ethical approval and patient consent were not necessarily needed.

2.1. Search strategy

Two investigators independently searched the database of PubMed, Embase, Cochrane Library, CNKI, Wanfang for published randomized controlled studies comparing PENG and FICB for perioperative analgesia in lower limb orthopedic surgery without language and publication status restrictions. The retrieval time is from the establishment of each database to December 2022. The following key words were used on combination with Boolean operators AND or OR: "(lower limb OR lower extremity) AND (pericapsular nerve group block) AND (fascia iliaca compartment block OR fascia iliaca block) AND (pain control)." Manually search for citations in key articles, related letters, reviews, and editorials to identify additional articles that the search strategy may have missed.

2.2. Inclusion and exclusion criteria

Inclusion criteria:

①Subjects: patients undergoing lower extremity orthopedic surgery, regardless of race, age, gender, height and weight;

② Intervention measures: Comparison of two kinds of nerve block in PENG and FICB under ultrasound guidance;

③ Study type: randomized controlled trial (RCTS);

④ Main outcome indicators: The pain scores at 10nim, 20min and 30min after nerve block, at 6h, 12h, 24h and 48h after surgery at resting state and exercise stateincluding visual analogue scale (VAS) pain score and numerical rating scale (NRS), which are all 0 ~ 10 points.

⑤ Secondary outcome indicators: the first analgesia time, intraoperative remfentanil consumption, fentanyl consumption at 24 hours after surgery, morphine consumption at 24 hours after surgery, satisfaction score for postoperative analgesia, quadriceps muscle strength at 6 and 24 hours after surgery, incidence of adverse reactions such as nausea and vomiting.

Exclusion criteria:

Case reports, reviews or conference papers;

② non-RCTs;

③ studies whose full text cannot be obtained, whose data cannot be extracted, and whose research was repeatedly published;

④animal experimental research.

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2.3. Literature screening and quality evaluation

The Cochran Manual Risk Bias Assessment tool (https://www.cochrane.org) was used to evaluate the methodological quality of the included literature [17]. The evaluation mainly included: random sequence generation, assignment hiding, double blindness of subjects and researchers, blind evaluation of outcomes, result data integrity, selective reporting of results, and other biases. The evaluation contents were divided into low bias, unclear bias risk or high bias risk. Two independent researchers independently screened and evaluated the quality of the retrieved literature in strict accordance with the inclusion and exclusion criteria. The extracted data included the name of the first author and the year of publication, sample size, age, sex, BMI, ASA classification, surgery time, medication of injection, major indexes, secondary indexes, etc.

2.4. Statistical Analysis

The Rev Man 5.3 software provided by the International Cochrane Collaboration network (https://www.cochrane.org/) was used for statistical analysis of the data. The measurement data were represented by mean difference (MD) and 95% confidence interval (CI). The effect size of dichotomous variables was represented by Relative Risk (RR) and 95%CI. Q test and I2 test were used to evaluate the heterogeneity between studies. When $P > 0.1$ and $I^2 < 50\%$, the heterogeneity of results was considered to be small, and fixed-effect model was used for analysis. Otherwise, the random-effect model was used to analyze the heterogeneity of the results. If $P < 0.05$, the difference is considered to be significant. At this point, publication bias can be intuitively judged by funnel plot, and sensitivity analysis can be conducted if necessary to explore the stability of results. For measurement data represented by median and quartile spacing, if there is no reply when contacted by the original author, the online calculator with compiled formulas by Wan et al. [18] and Luo et al. [19] will be used to convert the measurement data into standard deviation. Web Plot Digitizer was used to extract data when the research data was presented only with pictures and there was no response from the original author [20].

3. Results

3.1. Search result

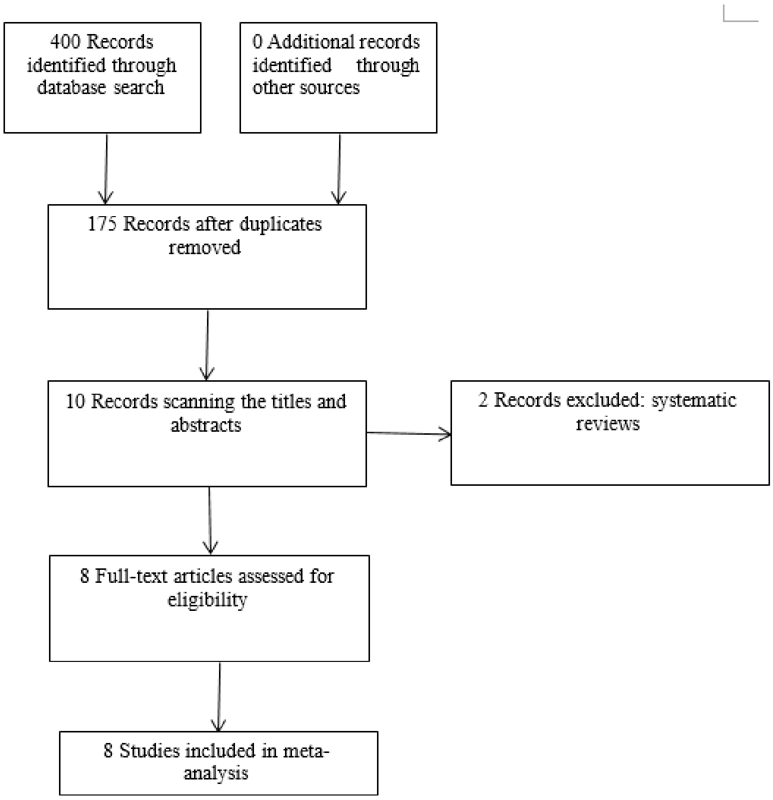

Figure 1: Literature screening flow chart

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The process of study selection was shown in Figure 1. A total of 400 studies were initially retrieved following the search strategy described above. 225 studies were excluded for duplication. By scanning the abstracts, 165 reports that did not meet inclusion criteria was excluded. After that, 10 studies were checked in full text for detailed evaluation. Finally, 8 RCTs included in the present meta-analysis, of which six were published in English and two were published in Chinese.

3.2 Study characteristics

The studies were published between 2021 and 2022 and the sample size of the included studies ranged from 24 to 95. All of them compare the analgesic efficiency between PENG and FICB in lower limb orthopedic surgery. Experimental groups received PENG, while control groups received FICB. There is a variation in dosage, concentration and types of local anesthetics among articles. (Table 1)

3.3 Risk of bias within studies

The risk assessment of literature bias is shown in Figure 2.

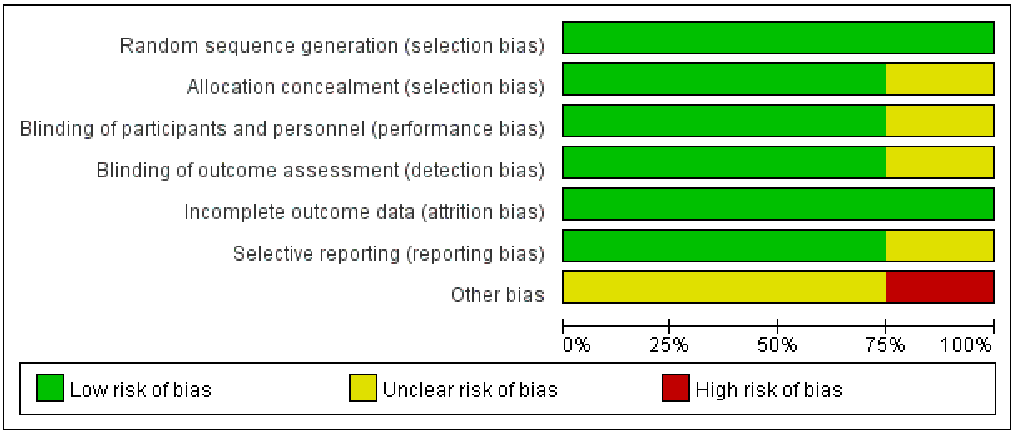

Figure 2: The risk assessment of literature bias

3.4 Outcomes for meta-analysis

3.4.1 Pain scores at resting states at different time points

There were four literatures [10, 13-15] that compared pain scores at resting state before nerve block, showing significant heterogeneity (I2=56%, P=0.08). Using the random effects model, meta-analysis results showed no statistical significance in pain scores at resting state before nerve block between the two groups (MD=-0.05, 95%CI -0.18 ~ 0.09, P=0.51, Figure 3A).

Two studies [12,15] compared pain scores at resting state 10min after nerve block, showing significant heterogeneity (I2=95%, P<0.01). The results of meta-analysis showed that the pain score at resting state 10min after nerve block in PENG group was significantly lower than that in FICB group (MD=-2.11, 95%CI - 2.39~ -1.82, P<0.01, Figure 3B).

Two studies [12,15] compared pain scores at resting state 20min after nerve block, showing significant heterogeneity (I2=95%, P<0.01). The results of meta-analysis showed that the pain score at resting state 20min after nerve block in PENG group was significantly lower than that in FICB group (MD=-1.73, 95%CI - 2.00~ -1.46, P<0.01, Figure 3C).

Two studies [10,12] compared pain scores at resting state 30min after nerve block, showing significant heterogeneity (I2=98%, P<0.01). Using random effects model, meta-analysis results showed that pain scores at resting state 30min after nerve block in PENG group were significantly lower than those in FICB group (MD=1.63, 95%CI 1.43 ~ -1.84, P<0.01, Figure 3D).

Five literatures [9-11, 13-14] compared the pain score at resting state 6h after surgery, showing significant heterogeneity (I2=92%, P<0.01). Using random effects model, meta-analysis results showed that the pain score at resting state 6h after surgery in PENG group was significantly lower than that in FICB group (MD=-1.27, 95%CI -1.44 ~ -1.09, P<0.01, Figure 3E).

Three literatures [11, 14-15] compared the pain score at resting state 12h after surgery, showing

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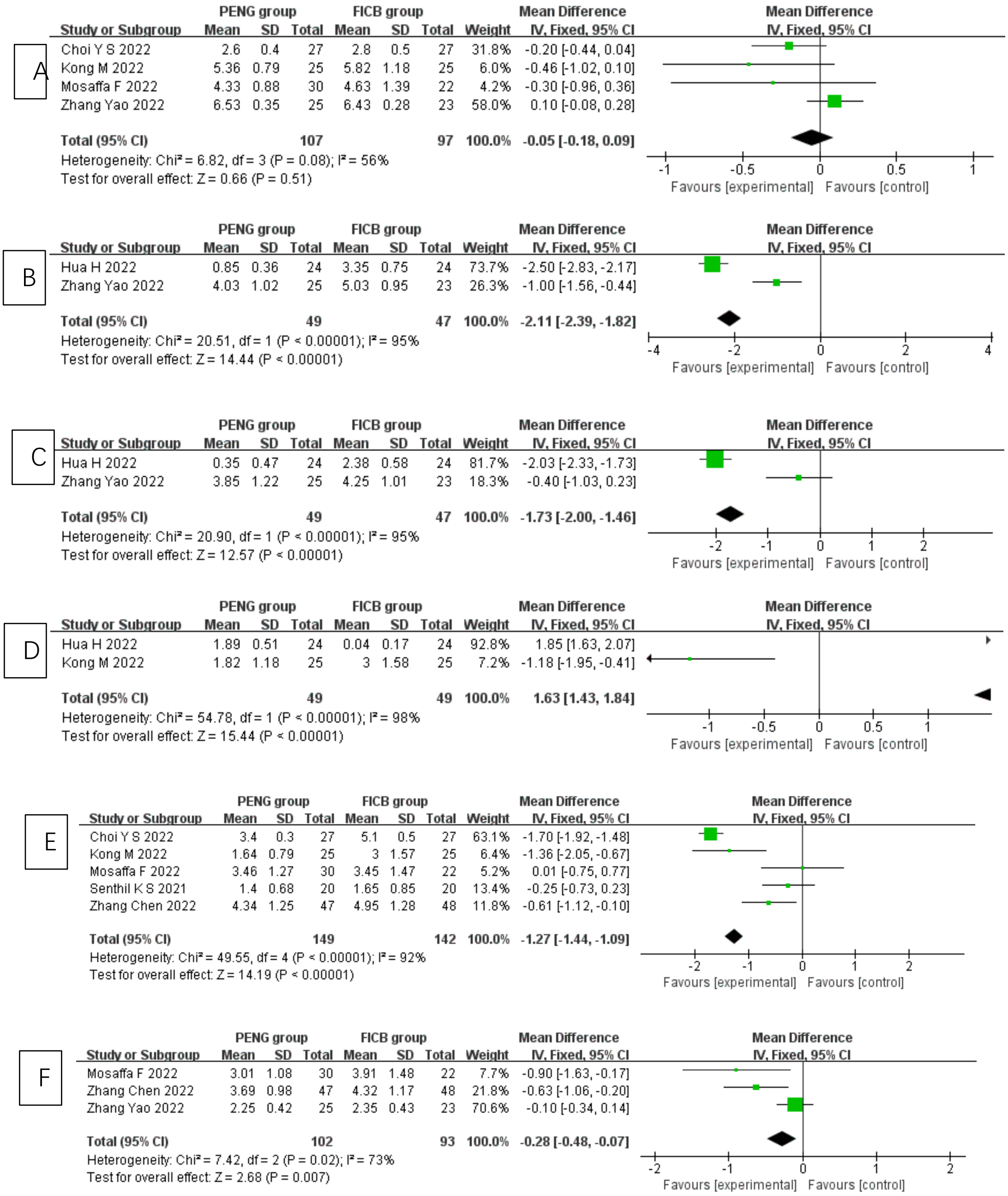
significant heterogeneity (I2=73%, P=0.02). Using the random effects model, meta-analysis results showed that the pain score at resting state 12h after surgery in PENG group was significantly lower than that in FICB group (MD=-0.28, 95%CI -0.48 ~ -0.07, P=0.007, Figure 3F).

Five literatures [9-11, 13, 15] compared the pain score at resting state 24h after surgery, showing significant heterogeneity (I2=96%, P<0.01). Using random effects model, meta-analysis results showed that the pain score at resting state 24h after surgery in PENG group was significantly lower than that in FICB group (MD=-0.49, 95%CI -0.61 ~ -0.37, P<0.01, Figure 3G).

There were four literatures [10-11,13, 15] that compared the 48h postoperative resting state pain score without significant heterogeneity (I2=0%, P=0.72). Using the fixed-effect model, meta-analysis results showed that the 48h postoperative resting state pain score of PENG group was significantly lower than that of FICB group (MD=-0.75, 95%CI -0.86 ~ -0.64, P<0.01, Figure 3H).



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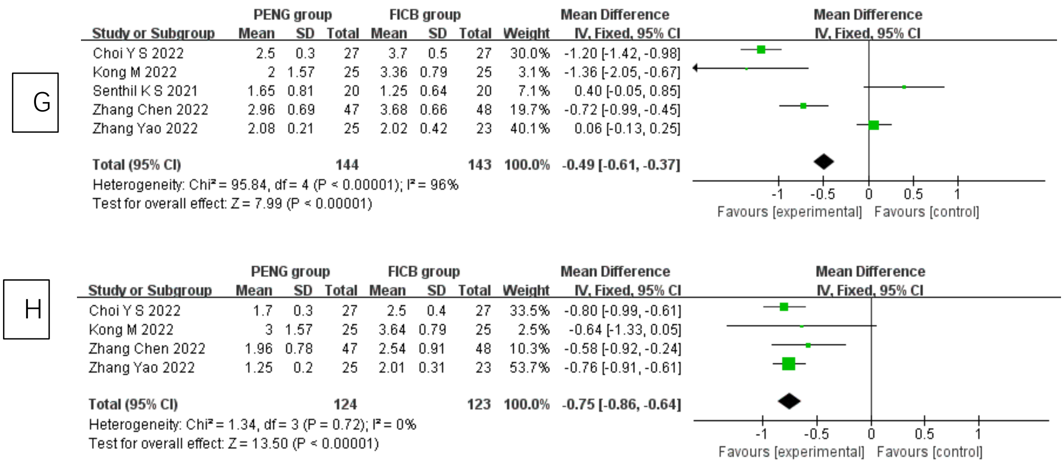

Figure 3: Pain scores at resting states at different time points

3.4.2 Pain scores at exercise states at different time points

There were four literatures [10, 12-13, 15] that compared the pain scores in the exercise state before nerve block, showing significant heterogeneity (I2=68%, P=0.02). Using the random effects model, the results of meta-analysis showed no statistical significance in the pain scores in the exercise state before nerve block between the two groups (MD=-0.04, 95%CI -0.18 ~ 0.09, P=0.56, Figure 4A).

Two studies [12,15] compared the pain scores of 10min after nerve block in exercise state, showing significant heterogeneity (I2=99%, P<0.01). The results of meta-analysis showed that the pain score of PENG group was significantly lower than that of FICB group (MD=-1.24, 95%CI - 1.41~ -1.06, P<0.01, Figure 4B) at the state of exercise 10min after nerve block.

Two studies [12,15] compared the pain scores of 20min after nerve block in motion state, showing significant heterogeneity (I2=98%, P<0.01). The results of meta-analysis showed that the pain score of 20min exercise state after nerve block in PENG group was significantly lower than that in FICB group (MD=-1.89, 95%CI - 2.23~ -1.54, P<0.01, Figure 4C).

Two studies [10,12] compared the pain scores at the exercise state 30min after nerve block, showing significant heterogeneity (I2=69%, P=0.07). The results of meta-analysis showed that the pain score of 20min exercise state after nerve block in PENG group was significantly lower than that in FICB group (MD=-1.20, 95%CI - 1.52~ -0.88, P<0.01, Figure 4D).

There were 4 literatures [9-11, 13] that compared the pain score of 6h postoperative exercise state, showing significant heterogeneity (I2=91%, P<0.01). Using random effects model, meta-analysis results showed that the pain score of 6h postoperative exercise state in PENG group was significantly lower than that in FICB group (MD=-1.01, 95%CI -1.19 ~ -0.83, P<0.01, Figure 4E).

Two literatures [11,15] compared 12h postoperative exercise state pain score without significant heterogeneity (I2=0%, P=0.32). Using the fixed-effect model, meta-analysis results showed that the pain score of 12h postoperative exercise state in PENG group was significantly lower than that in FICB group (MD=-0.54, 95%CI -0.75 ~ -0.34, P<0.01, Figure 4F).

Five literatures [9-11, 13, 15] compared the pain score of 24h postoperative exercise state, showing significant heterogeneity (I2=90%, P<0.01). Using the random effects model, meta-analysis results showed that the pain score of 24h postoperative exercise state in PENG group was significantly lower than that in FICB group (MD=-0.61, 95%CI -0.75 ~ -0.47, P<0.01, Figure 4G).

There were four literatures [10-11, 13, 15] that compared the pain score at 48h postoperative exercise state, showing significant heterogeneity (I2=72%, P=0.01). Using the random effects model, the results of meta-analysis showed that the pain score at 48h postoperative exercise state in PENG group was significantly lower than that in FICB group (MD=-0.37, 95%CI -0.54 ~ -0.19, P<0.01, Figure 4H).

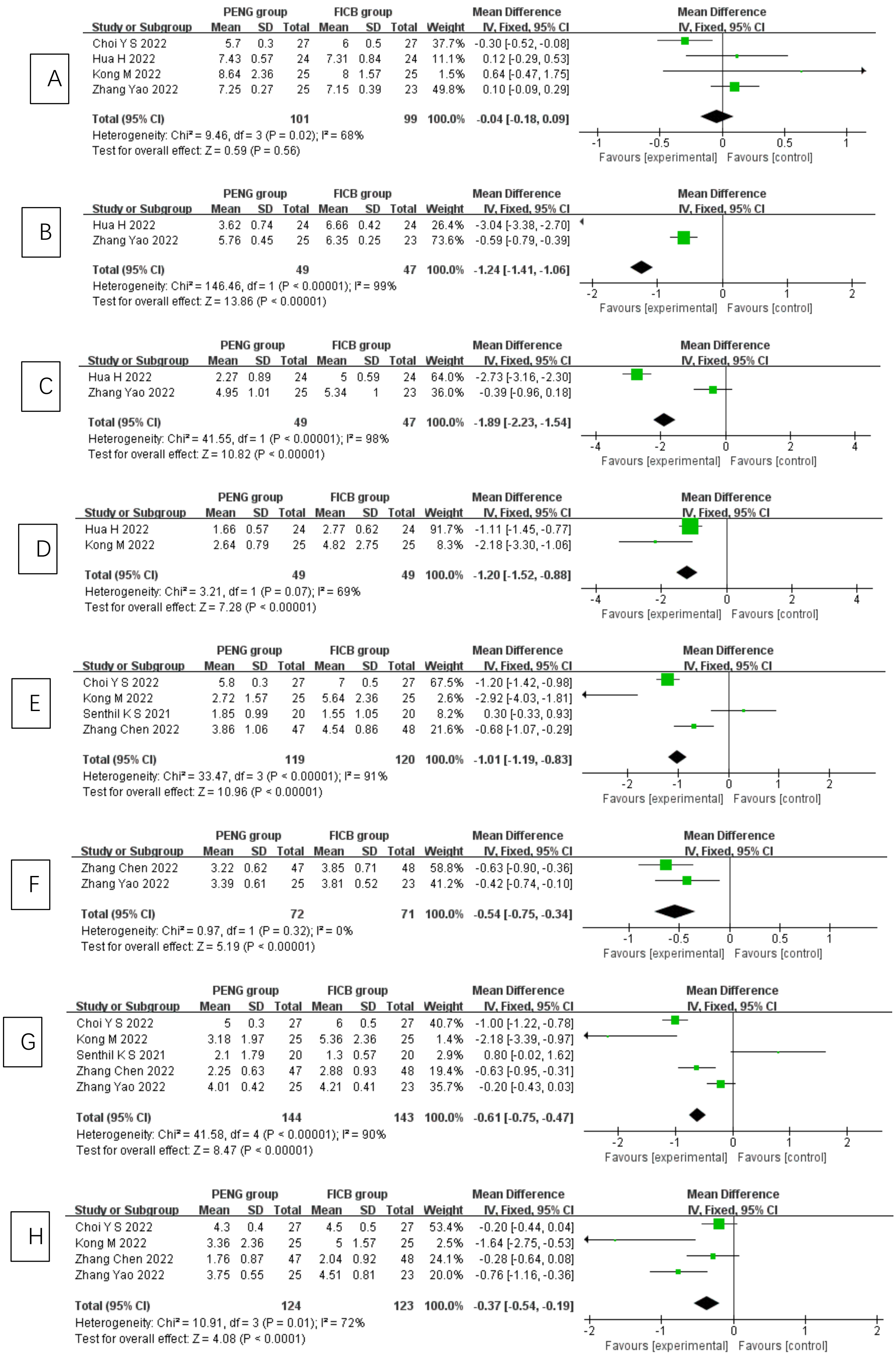

Figure 4: Pain scores at exercise states at different time points

3.4.3 The time of first analgesia

Three literatures [8, 11,14] compared the time of first postoperative analgesia, showing significant heterogeneity (I2=67%, P=0.05). Using random effects model, meta-analysis results showed that the time of first postoperative analgesia in PENG group was significantly later than that in FICB group (MD=3.60, 95%CI 2.86-4.34, P<0.01, Figure 5).

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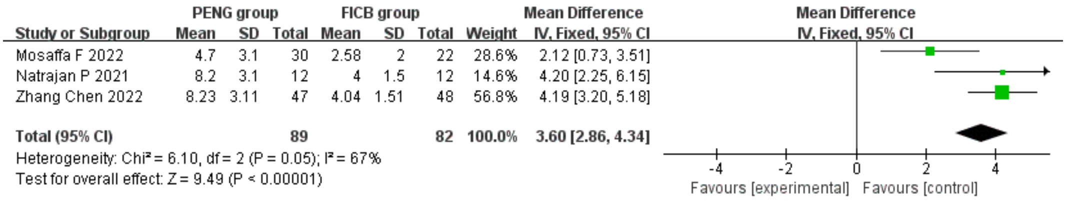

Figure 5: The time of first analgesia

3.4.4 The dosage of opioids used

Two studies [10,15] compared intraoperative remifentanil consumption without significant heterogeneity (I2=0%, P=0.44). Using the fixed-effect model, meta-analysis results showed that intraoperative remifentanil consumption in group PENG was significantly lower than that in group FICB (MD=-74.45, 95%CI - 96.53~ -52.37, P<0.01, Figure 6A).

Three studies [9-10,12] compared the consumption of fentanyl 24h after surgery, showing significant heterogeneity (I2=95%, P<0.01). Using the random effects model, meta-analysis results showed that the consumption of fentanyl 24h after surgery in PENG group was significantly lower than that in FICB group (MD=-4.59, 95%CI -7.33 ~ -1.84, P<0.01, Figure 6B).

Two studies [13-14] compared 24h morphine consumption without significant heterogeneity (I2=35%, P=0.22). Using the fixed-effect model, meta-analysis results showed that 24h morphine consumption in PENG group was significantly lower than that in FICB group (MD=-13.11, 95%CI - 16.95~ -9.27, P<0.01, Figure 6C).

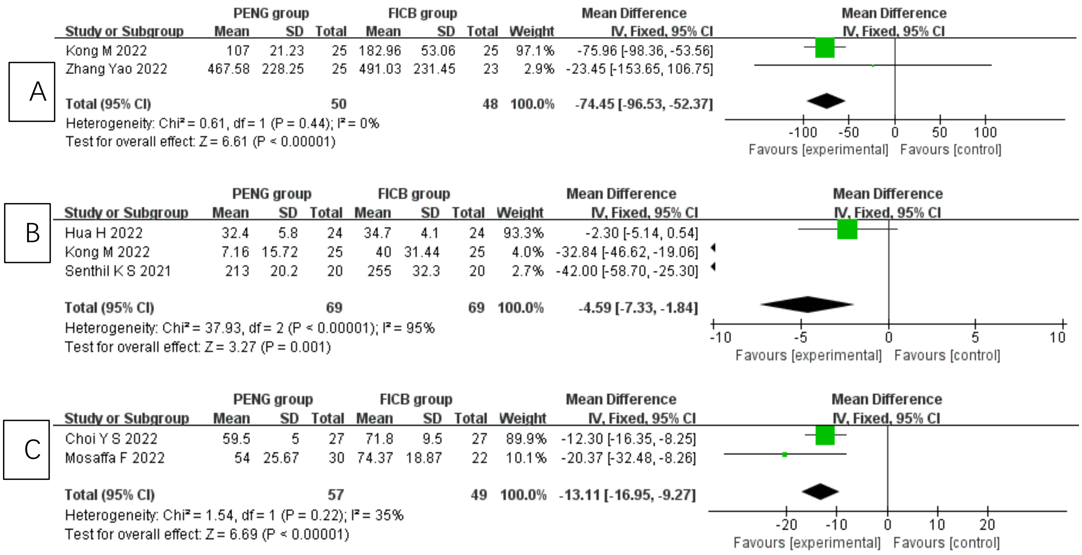

Figure 6: The dosage of opioids used

3.4.5 The postoperative analgesia satisfaction score

Three literatures [10,12-13] compared postoperative analgesic satisfaction scores, showing significant heterogeneity (I2=72%, P=0.03). Using random effects model, meta-analysis results showed that postoperative analgesic satisfaction scores in PENG group were significantly higher than those in FICB group (MD=0.25, 95%CI 0.03~0.48, P=0.03, Figure 7).

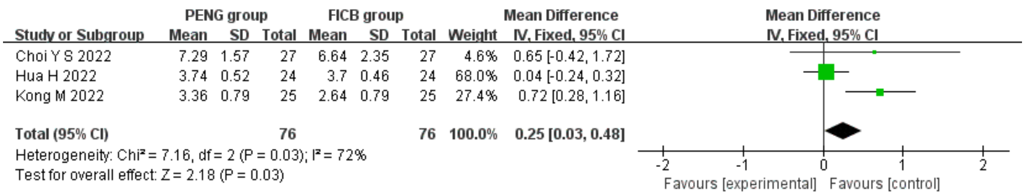

Figure 7: The postoperative analgesia satisfaction score

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3.4.6 Quadriceps muscle strength at different time points

Two literatures [9,13] compared quadriceps muscle strength 6h after surgery without significant heterogeneity (I2=0%, P=0.61). Using fixed effect model, meta-analysis results showed that quadriceps muscle strength of PENG group 6h after surgery was significantly higher than that of FICB group (MD=0.70, 95%CI 0.22~-1.18, P=0.004, Figure 8A).

Three literatures [9,13,15] compared quadriceps muscle strength 24h after surgery, showing significant heterogeneity (I2=95%, P<0.01). Using random effects model, meta-analysis results showed that quadriceps muscle strength in PENG group was significantly higher than that in FICB group 24h after surgery (MD=0.44, 95%CI 0.22~-0.65, P<0.01, Figure 8B).

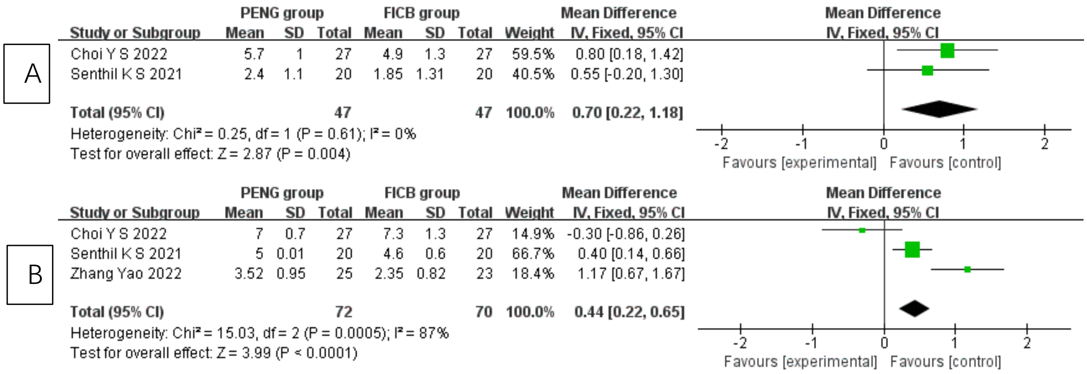

Figure 8: Quadriceps muscle strength at different time points

3.4.7 The occurrence of postoperative nausea and vomiting

Four literatures [8,10-11,13] mentioned the occurrence of postoperative nausea and vomiting without significant heterogeneity (I2=16%, P=0.31). Using the fixed-effect model, meta-analysis results showed that there was no statistical significance in the incidence of postoperative nausea and vomiting between the two groups (RR=0.94, 95%CI 0.45~1.97, P=0.87, Figure 9).

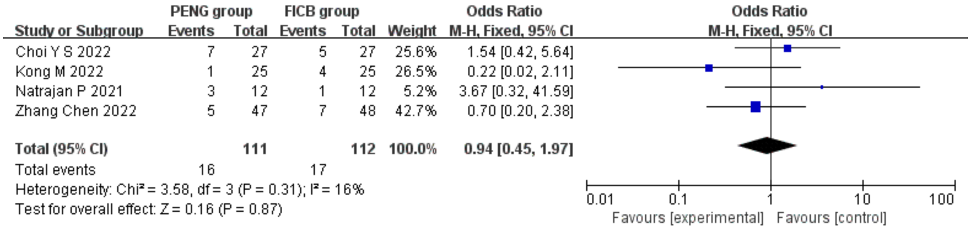

Figure 9: The occurrence of postoperative nausea and vomiting

3.4.8 Results of reporting bias

Funnel plots were drawn based on pain scores of 24 exercise states in the two groups after surgery. Funnel plots were distributed symmetrically, and the results suggested that publication bias was relatively small. (Figure 10)

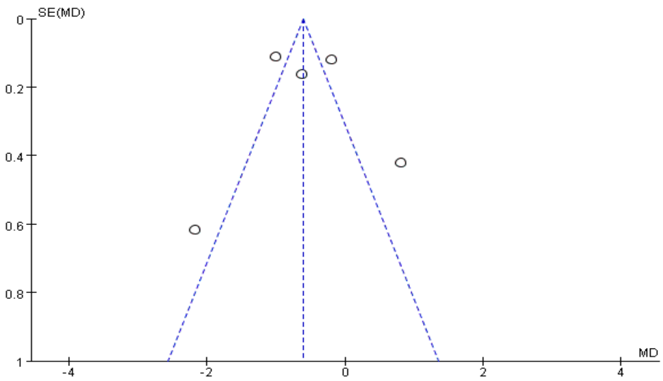

Figure 10: Publication bias funnel plot of exercise-state pain score 24h after surgery

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4. Discussion

A total of 411 patients were included in 8 RCTS in this study to directly evaluate the analgesic effects and adverse effects of ultrasuct-guided PENG and FICB on patients undergoing lower extremity orthopedic surgery. By analyzing the pooled data, our overall results show that ultrasound guided PENG can make patients with lower limb orthopedic surgery obtain better analgesic effect and satisfaction, while not affecting the muscle strength of the affected limb.

Fascia iliaca space block (FICB) was first proposed by Dalens et al. [21], whose research showd that compartment anesthesia diffusion in the iliac space can block the femoral nerve, the lateral femoral cutaneous nerve and the obturator nerve at the same time. It could achieve the same analgesic effect as the traditional "three-in-one" femoral nerve block [22], providing good perioperative analgesia for lower limb surgery, especially hip and knee surgery, and speeding up postoperative rehabilitation of patients. However, in recent years, with the deepening of studies, researchers found that FICB drugs spread between fascia and could not fully block the obturator nerve effectively, resulting in poor analgesic effect and long onset time[23]. Percapsular nerve group (PENG) block was a new regional nerve block anesthesia method, which was located between the anterior inferior iliac spine and the Iliopubiceminence and could block the femoral nerve joint branch, obturator nerve and accessory obturator nerve [24]. It was first used by Giron -Arango et al. [25] in 2018 for hip fracture surgery. Now it is gradually applied to lower limb amputation, great saphenous vein varicose ligation and dissection and mass resection of the inner thigh and other lower limb operations. As PENG was simple and could perfectly block obturator nerve, produce good perioperative analgesia, reduce opioid demand and related adverse reactions, and did not affect lower limb muscle strength, many experts at home and abroad had increasingly heated up their research in recent years. The anatomical characteristics of FICB and PENG were basically consistent with the results of meta-analysis in this study.

This systematic review has the following deficiencies: (1) Some studies in the included literature have different methods of anesthesia, localization methods of nerve block, and concentration and dose of local anesthesia drugs, which may increase clinical heterogeneity; (2) The evaluation methods of pain degree are different among different studies, which may cause measurement bias. In combination with the above deficiencies and limited by the number of original studies, the conclusions of this study still need to be verified by multi-center, large sample and high-quality RCTS.

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Table 1 Included literature

literature	Sample size		Age(y)		Sex(male/female)		ASA classification (I/II/III)		BMI (kg/m2)		Surgery time (min)		medication of injection		Outcome measures	
	PENG group	FICB group	PENG group	FICB group	PENG group	FICB group	PENG group	FICB group	PENG group	FICB group	PENG group	FICB group	PENG group	FICB group	PENG group	FICB group
Natrajan P,2021[8]	12	12											20 mL of 0.5% ropivacaine	20 mL of 0.5% ropivacaine	17,24	
Senthil KS,2021[9]	20	20	53.9±9.9	52.5±9.8	10/10	12/8	0/9/11	0/7/13					30 mL 0.25% levobupivacaine with 4 mg dexamethasone	30 mL 0.25% levobupivacaine with 4 mg dexamethasone	5,7,13,15,19,22,23	
Kong M,2022[10]	25	25	73.4 ± 5.9	72.8 ± 4.8	12/13	10/15	0/7/18	0/5/20	25.6 ± 1.9	25.7 ± 1.9	87.7 ± 20.7	87.6 ± 18.7	30 mL of 0.375% ropivacaine	30 mL of 0.375% ropivacaine	1,4,5,7,8,9,12,13,15,16,18,19,21,24	
Zhang Chen,2022[11]	47	48	67.63 ± 7.24	70. 61 ± 7.41	29/18	32/16	0/22/25	0/25/23	23.93 ± 3. 51	23.81 ± 2.77	82.61 ± 17.81	84.49 ± 13.10	20 mL 0.5% levobupivacaine	20 mL 0.5% levobupivacaine	5,6,7,8,13,14,15,16,17,24	
Hua H,2022[12]	24	24	74 ± 7	74±8	14/10	13/11	0/6/18	0/7/17	24±3	23±4	133±13	129 ± 19	0.4% ropivacaine 20 mL	0.4% ropivacaine 20 mL	2,3,4,9,10,11,12,19,21	
Choi YS,2022[13]	27	27	61.0 (48.5–72.0)	63.0 (52.0–71.0)	14/13	16/11	5/15/7	2/22/3	25.8 ± 3.0	25.0 ± 3.9	69.0 (57.0–78.0)	71.0 (60.0–80.5)	0.2% ropivacaine 20 mLwith epinephrine 1:200,000	0.2% ropivacaine 20 mLwith epinephrine 1:200,000	1,5,7,8,9,13,15,16,20,21,22,23,24	
Mosaffa F,2022[14]	30	22	53±16.46	50±13.63	22/8	16/6							3 ml/kg (a maximum of 40 ml) of ropivacaine 0.5%	3 ml/kg (a maximum of 40 ml) of ropivacaine 0.5%	1,5,6,17,20	
Zhang Yao,2022[15]	25	23	74±6	73±7	12/13	11/12	0/11/14	0/13/10	24.5 ± 2.3	24.2± 2.5	71.24 ±12.28	73.25± 11.48	30 mL of 0.33% ropivacaine	30 mL of 0.33% ropivacaine	1,2,3,6,7,8,9,10,11,14,15,16,18,23	

Note: 1, 2, 3, 4, 5, 6, 7 and 8 were the pain scores of resting state before block, 10 min after block, 20 min after block, 30 min after block, 6 h after surgery, 12 h after surgery, 24 h after surgery and 48 h after surgery. 9, 10, 11, 12, 13, 14, 15 and 16 were the pain scores of exercise state before block, 10 min after block, 20 min after block, 30 min after block, 6 h after surgery, 12 h after surgery, 24 h after surgery, and 48 h after surgery. 17 was the time of first analgesia; 18 was the total intraoperative remifentanil consumption; 19 was the total consumption of fentanyl at 24 hours postoperatively; 20 was the total dose of morphine consumed during 24 hours; 21 was the postoperative analgesia satisfaction score; 22 and 23 were the muscle strength of the quadriceps muscle 6 h and 24 h after surgery, respectively; 24 was the occurrence of postoperative nausea and vomiting.