Cite as: Tao T, Tan QL, Yin HL, Fang ZJ, Zhang WW, Zhang Y. The effects of different concentrations of ropivacaine on rebound pain following nerve blockade in ankle fracture patients [J]. Chin J Clin Res, 2026, 39(3):342-346.

DOI: 10.13429/j.cnki.cjcr.2026.03.004

The effects of different concentrations of ropivacaine on rebound pain following nerve blockade in ankle fracture patients

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Abstract: **Objective** To explore the differences in the incidence and pain intensity of rebound pain after nerve block with different concentrations of ropivacaine in patients with ankle fractures, in order to provide a basis for optimizing perioperative analgesia protocols. **Methods** A total of 88 patients who underwent elective open reduction and internal fixation for ankle fractures under general anesthesia at Nanjing First Hospital from January to December 2023 were prospectively selected and randomly divided into two groups using a random number table: the high-concentration group (n=44) and the low-concentration group (n=44). Before anesthesia induction, patients in both groups received a single ultrasound-guided adductor canal block combined with a popliteal sciatic nerve block. The low-concentration group received 40 mL of 0.125% ropivacaine, while the high-concentration group received 40 mL of 0.375% ropivacaine. All patients received perioperative multimodal analgesia. The incidence, intensity, and duration of rebound pain within 48 hours postoperatively were recorded for both groups. Resting Numeric Rating Scale (NRS)scores were recorded at 6 h, 12 h, 24 h, and 48 h postoperatively. Lovett muscle strength grading of the lower leg was recorded at 24 h and 48 h postoperatively. The time to first patient - controlled intravenous analgesia (PCIA)press, as well as the number of effective PCIA presses and rescue analgesic administrations within 48 hours postoperatively were recorded. Adverse reactions were also documented. **Results** There was no statistically significant difference in the duration of rebound pain between the two groups (P>0.05). The incidence of rebound pain within 48 hours postoperatively was lower in the low-concentration group than in the high-concentration group [13.6% (6/44)*vs* 40.9% (18/44), χ^2=8.250, P=0.004]. The NRS score at 12 hours postoperatively was significantly lower in the high-concentration group compared to the low- concentration group [1 (1, 2) *vs* 2 (1, 3), Z=2.157, P=0.031], while the NRS score at 24 hours postoperatively was significantly higher in the high-concentration group [4 (3, 5)*vs* 3 (2, 4), Z=2.132, P=0.033]. The time to first PCIA press postoperatively was significantly earlier in the low-concentration group than that in the high-concentration group (P<0.05). The number of effective PCIA presses and rescue analgesic administrations within 48 hours postoperatively were significantly lower in the low-concentration group compared to the high-concentration group (P<0.05). Lower leg muscle strength at 24 hours postoperatively was higher in the low-concentration group than that in the high-concentration group (P<0.05), but no significant difference was observed at 48 hours postoperatively (P>0.05). **Conclusion** The use of low-concentration ropivacaine for nerve block is associated with a lower incidence and milder intensity of rebound pain. Adductor canal block combined with sciatic nerve block using low-concentration ropivacaine is more suitable for perioperative multimodal analgesia in patients with ankle fractures.

Keywords: Ankle fracture; Nerve block; Rebound pain; Rest pain; Ropivacaine; Patient - controlled intravenous analgesia; Muscle strength

Acute pain is common after ankle fracture surgery, and pain management is particularly important to ensure patient comfort and promote recovery [1]. As a precise analgesic technique, peripheral nerve block has been widely used in ankle fracture surgery. This approach not only provides effective pain control but also reduces reliance on opioids, thereby accelerating postoperative recovery [1-2]. However, in recent years, severe pain that occurs after the resolution of nerve block—known as "rebound pain"—has become a major clinical concern [3]. Rebound pain is characterized by acute onset, rapid progression, high peak intensity, and unpredictability. It not only increases patient suffering but may also impair the quality and progress of postoperative rehabilitation [4-5]. Therefore, how to effectively prevent and manage rebound pain has become an urgent issue in current clinical practice. Young female sex and orthopedic surgery are considered high-risk factors for rebound pain [4,6]. Studies have shown that 0.1% ropivacaine for epidural block achieves satisfactory labor analgesia without affecting maternal motor function [7]. However, it remains unclear whether 0.125% ropivacaine can reduce the incidence of rebound pain after adductor canal block combined with popliteal sciatic nerve block. Accordingly, this study aimed to investigate the effects of two different concentrations of ropivacaine on rebound pain following nerve block in patients undergoing ankle fracture surgery, so as to provide evidence for optimizing postoperative analgesic regimens.

1 Materials and Methods

1.1 General Data

This study was approved by the Ethics Committee of Nanjing First Hospital (No. KY20240125-03), and written informed consent was obtained from all patients. Patients scheduled for elective open reduction and internal fixation

(ORIF) of ankle fractures under general anesthesia at Nanjing First Hospital from January 2023 to December 2023 were enrolled. According to a preliminary experiment, the primary outcome was the incidence of rebound pain at 48 h postoperatively, which was 12% in the low-concentration group and 38% in the high-concentration group. Assuming a two-sided $\alpha = 0.05$ and a test power of $1-\beta = 0.80$, a total of 80 patients were required. Considering a 10% dropout rate, 88 patients were finally included.

Inclusion criteria:(1) aged 18–65 years; (2) American Society of Anesthesiologists (ASA) physical status Grade I–II; (3) body mass index (BMI) 18–30 kg/m²; (4) scheduled for open reduction and internal fixation of ankle fracture under general anesthesia.

Exclusion criteria: (1) isolated malleolar fracture, multiple injuries or fractures; (2) coagulation dysfunction, local or systemic infection; (3) long-term opioid use, allergy to local anesthetics; (4) complicated with peripheral neuropathy or history of chronic pain; (5) cognitive dysfunction or inability to communicate.

Drop out and withdraw criteria: (1) occurrence of severe perioperative complications; (2) reoperation; (3) patient withdrawal from the study.

1.2 Grouping and Intervention

Patients were randomly assigned to two groups using a computer-generated random number list in sealed opaque envelopes: a high-concentration group and a low-concentration group. There was no significant difference in general data between the two groups (P>0.05). See **Table 1**.

Tab.1 Comparison of general data of the two groups (n=44)

Group	Age (years)[a]	Male/ Female[b]	BMI (kg/m²)[a]	ASA Classification (Grade I/II)[b]	Fracture Type (Bimalleolar/Trimalleolar)[b]	Operative Side (Left/Right)[b]	Operation Time (min)[a]	Preoperative NRS Score[c]
Low-concentration group	46.4±15.4	22/22	24.8±3.6	29/15	28/16	19/25	90.3±30.0	2(2,4)
High-concentration group	46.3±13.2	25/19	24.0±3.7	26/18	12/32	21/23	87.5±28.1	2(2,4)
***t*/χ2/*Z* Value**	0.022	0.411	1.035	0.436	0.838	0.183	0.455	0.63
***P* Value**	0.982	0.521	0.304	0.509	0.36	0.669	0.651	0.529

Note: [a] Data are expressed as $\bar{x}\pm s$; [b] Data are expressed as case; c Data are expressed as M (P_{25}, P_{75})

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1.2.1 Nerve Block

After entering the operating room, all patients received routine electrocardiographic monitoring and intravenous access establishment, followed by ultrasound-guided adductor canal block and popliteal sciatic nerve block. The affected lower limb was externally rotated at the hip with the knee flexed. After routine disinfection and draping, a high-frequency linear ultrasound probe was placed on the medial mid-thigh to identify the sartorius muscle, adductor longus muscle, vastus medialis muscle, and femoral artery. Using an in-plane technique, the nerve block needle was advanced into the adductor canal. After negative aspiration for blood, 20 mL of ropivacaine (Zhejiang Xianju Pharmaceutical, National Medical Products Approval No. H20163208, 10 mL:75 mg) was injected into the lateral triangular space around the femoral artery. The patient was then placed in the lateral decubitus position. After routine disinfection and draping, an out-of-plane approach was used. The tail of the ultrasound probe was tilted slightly cephalad to clearly visualize the sciatic nerve, its bifurcation, and the paraneural sheath. A distinct elastic deformation and distortion of the paraneural sheath could be observed as the needle tip penetrated it, accompanied by an obvious “pop” sensation. A small volume of local anesthetic was injected to confirm spread within the paraneural sheath and between the two nerve divisions, while ensuring the needle tip was clearly visible and located in the safe zone of the sciatic nerve bifurcation. After negative aspiration, a total of 20 mL of local anesthetic was administered. Patients in the low-concentration group received 40 mL of 0.125% ropivacaine, and those in the high-concentration group received 40 mL of 0.375% ropivacaine. All nerve blocks were performed by the same experienced anesthesiologist.

1.2.2 General Anesthesia

Anesthesia induction: intravenous midazolam (Jiangsu Enhua Pharmaceutical, H10980025, 2 mL:10 mg) 0.03 mg/kg, sufentanil (Yichang Renfu Pharmaceutical, H20054171, 1 mL:50 μg) 0.5 μg/kg, propofol (Fresenius Kabi Austria GmbH, HJ20191011, 20 mL:0.2 g) 2 mg/kg, and rocuronium (Zhejiang Beisheng Pharmaceutical Hansheng Pharmaceutical, H20213778, 5 mL:50 mg) 0.6 mg/kg. Anesthesia maintenance: propofol 2–5 $mg\cdot kg^{-1}\cdot h^{-1}$, remifentanil (Yichang Renfu Pharmaceutical, H20030197) 6–24 $\mu g\cdot kg^{-1}\cdot h^{-1}$, and rocuronium 0.3–0.6 $mg\cdot kg^{-1}\cdot h^{-1}$. Intraoperative end-tidal partial pressure of carbon dioxide was maintained at 35–45 mmHg, and bispectral index (BIS) at 40–60. Vasoactive agents were used to keep fluctuations in heart rate and blood pressure within 20% of baseline values. All surgeries were performed by the same experienced orthopedic surgeon, and a thigh tourniquet was applied in all cases. Tropisetron (Shandong Yikang Pharmaceutical, H20163418, 2 mL:2 mg) 4 mg was administered intravenously 30 min before the end of surgery to prevent postoperative nausea and vomiting.

1.2.3 Postoperative Analgesia

All patients received patient-controlled intravenous analgesia (PCIA): sufentanil 150 μg + tropisetron 6 mg, diluted to 250 mL with normal saline, background infusion rate 3 mL/h, bolus dose 5 mL, lockout interval 8 min. Patients were instructed to activate PCIA independently when they perceived resolution of the nerve block effect, and to press the bolus button when experiencing severe pain. If the Numerical Rating Scale (NRS) score [8] was ⩾4 after three consecutive boluses, rescue analgesia was provided with intravenous flurbiprofen axetil (Beijing Tide Pharmaceutical, H20041508, 5 mL:50 mg) 50 mg.

1.3 Observation Indexes

(1) The incidence, severity, and duration of rebound pain within 48 h postoperatively were recorded in both groups. Rebound pain was defined as an NRS score ⩾7 at the surgical site after resolution of the nerve block. (2) Resting NRS scores were recorded at 6, 12, 24, and 48 h postoperatively. (3) Calf muscle strength was assessed at 24 and 48 h postoperatively using the Lovett muscle strength grading system [9], graded 0 to 5 and scored 0 to 5 points. (4) Time to first PCIA activation, number of effective PCIA boluses, and number of rescue analgesic administrations within 48 h postoperatively were recorded. (5) Adverse events were documented, including nausea, vomiting, and nerve block-related complications. (6) Patients were instructed to keep a pain diary, and follow-up assessments were performed by dedicated investigators at scheduled time points.

1.4 Statistical Analysis

Statistical analysis was performed using SPSS 22.0 software. Normally distributed measurement data were expressed as $\bar{x}\pm s$, and between-group comparisons were performed using independent-samples *t*-test. Non-normally distributed data were expressed as median (25th percentile, 75th percentile) [$M(P_{25},P_{75})$], and between-group comparisons were performed using the Mann-Whitney U test. Repeated-measures data at multiple time points were analyzed using the Friedman test. Enumeration data were expressed as cases (%) and analyzed using the χ^2 test. $P<0.05$ was considered statistically significant.

2 Results

2.1 Incidence of Postoperative Rebound Pain

Compared with the high-concentration group, the low-concentration group had a significantly lower incidence and NRS score of rebound pain within 48 h postoperatively ($P<0.05$). There was no significant difference in the duration of rebound pain between the two groups ($P>0.05$). See **Table 2.**

2.2 Postoperative Resting NRS Scores

There was no significant difference in NRS scores between the two groups at 6 h and 48 h postoperatively ($P>0.05$). The NRS score at 12 h postoperatively was significantly lower in the high-concentration group than in the low-concentration group ($P<0.05$), whereas the NRS score at 24 h postoperatively was significantly higher in the high-concentration group ($P<0.05$). See **Table 3**.

2.3 Postoperative Analgesia-Related Parameters

Time to first PCIA activation was significantly earlier in the low-concentration group than in the high-concentration group ($P<0.05$), whereas the number of effective PCIA boluses and rescue analgesic administrations within 48 h postoperatively were significantly lower in the low-concentration group ($P<0.05$). See **Table 4**.

2.4 Postoperative Adverse Events and Calf Muscle Strength

No nerve block-related complications were observed in either group postoperatively. There was no significant difference in the incidence of nausea and vomiting or calf muscle strength at 48 h postoperatively between the two groups ($P>0.05$). Calf muscle strength at 24 h postoperatively was significantly better in the low-concentration group than in the high-concentration group ($P<0.05$). See **Table 5**.

Tab.2 Comparison of the incidence, pain severity, and duration of rebound pain within 48 h after surgery [n=44, $M(P_{25},P_{75})$]

Group	Rebound Pain [case(%)]	NRS Score (points)	Duration (h)
Low-concentration group	6(13.6)	8(7,9)	3.6(3.1,4.5)
High-concentration group	18(40.9)	9(8,10)	3.5(2.7,4.0)
χ^2/Z Value	8.25	2.09	0.635
P Value	0.004	0.047	0.525

Tab.3 Comparison of the postoperative NRS scores [n=44, point, $M(P_{25},P_{75})$]

Group	Postoperatively				χ^2 Value	*P* Value
	6 h	12 h	24 h	48 h		
Low-concentration group	0(0,1)	2(1,3)	3(2,4)	3(2,3)	117.055	<0.001
High-concentration group	0(0,0)	1(1,2)	4(3,5)	3(2,4)	122.186	<0.001
Z Value	1.187	2.157	2.132	0.138		
P Value	0.235	0.031	0.033	0.89		

Tab.4 Comparison of the postoperative analgesia indexes between two groups (n=44)

Group	Time to First Press (min)	Number of Effective Presses	Number of Rescue Analgesia
Low-concentration group	300.6±74.2	15.5±5.0	0(0,1)
High-concentration group	623.1±99.8	19.8±7.4	3(1,4)
t/Z Value	17.197	3.203	5.261
P Value	<0.001	0.002	<0.001

Tab.5 Comparison of postoperative adverse reactions and calf muscle strength between two groups (n=44)

Group	Nausea and Vomiting [case(%)]	Calf Muscle Strength [point, $M(P_{25},P_{75})$]	
		24 h Postoperatively	48 h Postoperatively
Low-concentration group	22(50.0)	1(1,2)	2(1,3)
High-concentration group	19(43.2)	0(0,1)	2(1,3)
χ^2/Z Value	0.411	4.313	1.442
P Value	0.521	<0.001	0.149

3 Discussion

Peripheral nerve block plays a key role in anesthesia and multimodal postoperative analgesia for orthopedic surgery. Its advantages include markedly reduced opioid consumption, better control of early postoperative pain, and shortened hospital stay [10-12]. However, rebound pain after resolution of peripheral nerve block may offset the benefits of this technique [13]. Ankle fracture is associated with severe trauma and requires early

postoperative rehabilitation training; thus, satisfactory postoperative analgesia is particularly important for these patients [2-3]. This study included patients with bimalleolar or trimalleolar fractures undergoing open reduction and internal fixation. The medial and lateral aspects of the ankle are innervated independently by the saphenous branch of the femoral nerve and the sciatic nerve. Therefore, we chose adductor canal block combined with popliteal sciatic nerve block.

The results of this study showed that the high-concentration group had a higher incidence and greater severity of rebound pain after resolution of the nerve block. Resolution of nerve block usually occurs rapidly, manifesting as an abrupt "on-off" transition [14], at which time plasma opioid analgesics may have been completely metabolized. Consequently, when the nerve block effect suddenly resolves, analgesia via the infusion pump may not provide timely and sufficient coverage for the breakthrough pain, leading to rebound pain.

In this study, compared with the high-concentration group, the low-concentration group had higher NRS scores at 12 h postoperatively and significantly shorter time to first PCIA activation, indicating shorter duration and weaker intensity of nerve block in the low-concentration group. At the same volume, the high-concentration group received a higher concentration and total dose of ropivacaine, resulting in a longer nerve block duration. However, NRS scores at 24 h postoperatively were significantly lower in the low-concentration group. The number of effective PCIA boluses and rescue analgesic administrations within 48 h postoperatively was significantly lower in the low-concentration group, suggesting that rebound pain increases postoperative intravenous opioid use, consistent with previous findings [15]. Due to the shorter duration and weaker intensity of nerve block in the low-concentration group, patients initiated PCIA earlier, maintaining a certain plasma concentration of sufentanil postoperatively. Thus, analgesia in the low-concentration group could transition smoothly from nerve block–based analgesia to intravenous analgesia.

Furthermore, this study showed that calf muscle strength at 24 h postoperatively was significantly better in the low-concentration group than in the high-concentration group, indicating that 0.125% ropivacaine has less impact on calf muscle strength. This facilitates early postoperative mobilization and functional exercise, and exerts a positive effect in preventing postoperative ankle adhesion. Most patients tolerate postoperative pain reasonably well; however, limb numbness, motor limitation, and rebound pain caused by peripheral nerve block with high-concentration local anesthetics may reduce overall patient satisfaction with postoperative nerve block analgesia [16].

This study has several limitations. First, only patients with ankle fractures were included; further clinical trials are needed to investigate the effects of different local anesthetic concentrations on rebound pain after other types of nerve blocks. Second, a thigh tourniquet was used in all patients during surgery, which may aggravate postoperative pain and affect measurement accuracy. Finally, only two concentrations were compared; it is necessary to expand the sample size to systematically explore the effects of a gradient of ropivacaine concentrations on rebound pain.

In conclusion, in multimodal analgesia after open reduction and internal fixation of ankle fractures, low-concentration ropivacaine for adductor canal block combined with popliteal sciatic nerve block results in a lower incidence and milder intensity of rebound pain after block resolution, reduces postoperative opioid consumption, and causes less impairment to muscle strength.

Conflict of Interest: None

Reference

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Submission Received: 2025-04-29 **Revised: 2025-07-10**

·临床麻醉专题·论著·

不同浓度罗哌卡因对踝关节骨折神经阻滞后反跳痛的影响

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摘要：目的　探讨不同浓度罗哌卡因与踝关节骨折神经阻滞后反跳痛发生及疼痛程度的差异，为优化围手术期镇痛方案提供依据。**方法**　前瞻性选择 2023 年 1 月至 12 月在南京市第一医院择期全身麻醉下行踝关节骨折切开复位内固定术的患者 88 例，按随机数字表法随机分为高浓度组（n=44）和低浓度组（n=44）。在麻醉诱导前，两组患者接受单次超声引导下收肌管阻滞以及腘窝坐骨神经阻滞，低浓度组患者使用 0.125% 罗哌卡因 40 mL，高浓度组患者使用 0.375% 罗哌卡因 40 mL。所有患者均接受围手术期多模式镇痛。记录以下数据：术后 48 h 的反跳痛发生率、疼痛程度以及持续时间，术后 6 h、12 h、24 h 及 48 h 的静息数字分级评分法（NRS）评分，术后 24 h 和 48 h 小腿 Lovett 肌力分级，静脉自控镇痛（PCIA）首次按压时间、术后 48 h 有效按压次数和补救镇痛次数，以及不良反应发生情况。**结果**　两组患者反跳痛持续时间差异无统计学意义（P>0.05）。低浓度组患者术后 48 h 内反跳痛的发生率低于高浓度组［13.6%（6/44）*vs* 40.9%（18/44），χ^2=8.250，P=0.004］。术后 12 h NRS 评分高浓度组显著低于低浓度组［1（1，2）*vs* 2（1，3），Z=2.157，P=0.031］，术后 24 h NRS 评分高浓度组显著高于低浓度组［4（3，5）*vs* 3（2，4），Z=2.132，P=0.033］。低浓度组患者术后 PCIA 首次按压时间早于高浓度组患者（P<0.01）。低浓度组患者术后 48 h PCIA 有效按压次数及补救镇痛次数少于高浓度组（P<0.05）。低浓度组患者术后 24 h 小腿肌力高于高浓度组（P<0.01），但术后 48 h 两组差异无统计学意义（P>0.05）。**结论**　低浓度罗哌卡因神经阻滞后反跳痛的发生率较低、疼痛程度较轻，低浓度罗哌卡因收肌管联合坐骨神经阻滞更适合踝关节骨折围手术期的多模式镇痛。

关键词：踝关节骨折；神经阻滞；反跳痛；静息痛；罗哌卡因；患者静脉自控镇痛；肌力

中图分类号：R614　**文献标识码：**A　**文章编号：**1674-8182（2026）03-0342-05

The effects of different concentrations of ropivacaine on rebound pain following nerve blockade in ankle fracture patients

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Abstract: Objective　To explore the differences in the incidence and pain intensity of rebound pain after nerve block with different concentrations of ropivacaine in patients with ankle fractures, in order to provide a basis for optimizing perioperative analgesia protocols. **Methods**　A total of 88 patients who underwent elective open reduction and internal fixation for ankle fractures under general anesthesia at Nanjing First Hospital from January to December 2023 were prospectively selected and randomly divided into two groups using a random number table: the high-concentration group (n=44) and the low-concentration group (n=44). Before anesthesia induction, patients in both groups received a single ultrasound-guided adductor canal block combined with a popliteal sciatic nerve block. The low-concentration group received 40 mL of 0.125% ropivacaine, while the high-concentration group received 40 mL of 0.375% ropivacaine. All patients received perioperative multimodal analgesia. The incidence, intensity, and duration of rebound pain within 48 hours postoperatively were recorded for both groups. Resting Numeric Rating Scale (NRS) scores were recorded at 6 h,

DOI: 10.13429/j.cnki.cjcr.2026.03.004

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出版日期：2026-03-20

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12 h, 24 h, and 48 h postoperatively. Lovett muscle strength grading of the lower leg was recorded at 24 h and 48 h postoperatively. The time to first patient-controlled intravenous analgesia (PCIA) press, as well as the number of effective PCIA presses and rescue analgesic administrations within 48 hours postoperatively were recorded. Adverse reactions were also documented. **Results** There was no statistically significant difference in the duration of rebound pain between the two groups (P>0.05). The incidence of rebound pain within 48 hours postoperatively was lower in the low-concentration group than in the high-concentration group [13.6%(6/44) *vs* 40.9%(18/44), χ^2=8.250, P=0.004]. The NRS score at 12 hours postoperatively was significantly lower in the high-concentration group compared to the low-concentration group [1(1, 2) *vs* 2(1, 3), Z=2.157, P=0.031], while the NRS score at 24 hours postoperatively was significantly higher in the high-concentration group [4(3, 5) *vs* 3(2, 4), Z=2.132, P=0.033]. The time to first PCIA press postoperatively was significantly earlier in the low-concentration group than that in the high-concentration group (P<0.05). The number of effective PCIA presses and rescue analgesic administrations within 48 hours postoperatively were significantly lower in the low-concentration group compared to the high-concentration group (P<0.05). Lower leg muscle strength at 24 hours postoperatively was higher in the low-concentration group than that in the high-concentration group (P<0.05), but no significant difference was observed at 48 hours postoperatively (P>0.05). **Conclusion** The use of low-concentration ropivacaine for nerve block is associated with a lower incidence and milder intensity of rebound pain. Adductor canal block combined with sciatic nerve block using low-concentration ropivacaine is more suitable for perioperative multimodal analgesia in patients with ankle fractures.

Keywords: Ankle fracture; Nerve block; Rebound pain; Rest pain; Ropivacaine; Patient-controlled intravenous analgesia; Muscle strength

踝关节骨折术后常伴有急性疼痛，为了确保患者舒适并促进康复，疼痛管理尤为重要[1]。周围神经阻滞作为一种精准的镇痛方法，在踝关节骨折术中得到广泛应用，这种方法不仅能够提供有效的疼痛控制，还能减少对阿片类药物的依赖，从而加速术后康复[1-2]。然而，近年来，神经阻滞作用消退后出现的剧烈疼痛现象——即“反跳痛”已成为临床关注的焦点[3]。反跳痛起病急、进展快、疼痛峰值高且不可预测，不仅增加患者痛苦，还可能影响术后康复质量与进程[4-5]。因此，如何有效预防和管理反跳痛，成为当前临床实践中亟需解决的问题。年轻女性、骨科手术被认为是发生反跳痛的高危因素[4,6]。有研究显示，0.1%罗哌卡因用于硬膜外阻滞能够实现良好的分娩镇痛效果，且不影响产妇的运动功能[7]。然而，0.125%罗哌卡因能否降低收肌管联合腘窝坐骨神经阻滞后反跳痛的发生率，仍尚不清楚。因此，本研究旨在观察两种不同浓度罗哌卡因对踝关节骨折手术的患者在神经阻滞后反跳痛的影响，为改进术后镇痛方案提供参考。

1 资料与方法

1.1 一般资料 本研究已获得南京市第一医院伦理委员会批准（编号：KY20240125-03），所有患者均签署知情同意书。选择2023年1月至2023年12月在南京市第一医院择期全身麻醉下行踝关节骨折切开复位内固定术的患者，根据预试验结果，主要结局指标为术后48 h的反跳痛发生率，低浓度组12%和高浓度组38%。假设双侧α=0.05，检验效能1-β=0.80，共需要患者80例。考虑到脱落率10%，共纳入88例患者。

纳入标准：（1）年龄18~65岁；（2）美国麻醉医师协会（American Society of Anesthesiologists，ASA）分级Ⅰ~Ⅱ级；（3）身体质量指数（body mass index，BMI）18~30 kg/m^2；（4）拟于全身麻醉下实施踝关节骨折切开复位内固定术。排除标准：（1）单踝骨折，多处受伤或骨折；（2）凝血功能障碍，局部或全身感染；（3）长期使用阿片类药物，对局部麻醉药（局麻药）过敏；（4）合并周围神经病变，慢性疼痛史；（5）存在认知功能障碍或无法沟通等。剔除标准：（1）围手术期出现严重并发症；（2）再次手术；（3）患者退出研究。

1.2 分组与处理 使用密封不透明信封，通过计算机生成的随机数字将患者分为两组：高浓度组和低浓度组。两组患者一般资料比较差异无统计学意义（P>0.05）。见表1。

1.2.1 神经阻滞 所有患者入室后常规心电监护、建立静脉通路，然后进行超声引导下收肌管阻滞及腘窝坐骨神经阻滞。患侧下肢大腿外旋、膝盖弯曲，常规消毒铺巾，将超声高频线性探头放置在大腿中部内侧，识别缝匠肌、长收肌、股内侧肌和股动脉，使用平面内技术，神经阻滞针到达收肌管内，回抽无血后将20 mL罗哌卡因（浙江仙琚制药，国药准字H20163208，10 mL∶75 mg）注射到股动脉的外侧三角形区域；将患者改侧卧位，常规消毒铺巾，选用平面外进针，超声探头尾部适当向头侧倾斜，使坐骨神经

及分叉处的结构及其神经旁鞘显示清晰。针尖进入神经旁鞘的过程中可明显见到神经旁鞘的弹性和受到外力后的扭曲变形。突破旁鞘时可有较明显的突破感。注射少量局麻药，确认局麻药在神经旁鞘内、两个神经之间的间隙内扩散，同时使针尖显示清楚，确保针尖在坐骨神经分叉的安全区域。回抽确认无回血，继续给予局麻药总量 20 mL。低浓度组患者使用 0.125% 罗哌卡因 40mL，高浓度组患者使用 0.375% 罗哌卡因 40 mL。神经阻滞由同一名经验丰富的麻醉医生实施。

1.2.2　全身麻醉　麻醉诱导：静脉注射咪达唑仑（江苏恩华药业，国药准字 H10980025，2 mL∶10 mg）0.03 mg/kg、舒芬太尼（宜昌人福药业，国药准字 H20054171，1 mL∶50 μg）0.5 μg/kg、丙泊酚（Fresenius Kabi Austria GmbH，国药准字 HJ20191011，20 mL∶0.2 g）2 mg/kg 和罗库溴铵（浙江北生药业汉生制药，国药准字 H20213778，5 mL∶50 mg）0.6 mg/kg。麻醉维持：丙泊酚 2~5 mg·kg^{-1}·h^{-1}、瑞芬太尼（宜昌人福药业，国药准字 H20030197）6~24 μg·kg^{-1}·h^{-1}、罗库溴铵 0.3~0.6 mg·kg^{-1}·h^{-1}。术中维持呼气末二氧化碳分压 35~45 mmHg、脑电双频指数（bispectral index，BIS）40~60，使用血管活性药物将心率和血压波动保持在基线的 20% 以内。所有患者的手术由同一名经验丰富的外科医生主刀实施，并且术中均使用了止血带。在手术结束前 30 min 静脉注射托烷司琼（山东益康药业，国药准字 H20163418，2 mL∶2 mg）4 mg，以防止术后恶心和呕吐。

1.2.3　术后镇痛　术后所有患者行静脉自控镇痛（patient-controlled intravenous analgesia，PCIA）镇痛（舒芬太尼 150 μg+托烷司琼 6 mg，加生理盐水配至 250 mL，背景剂量 3 mL/h，冲击剂量 5 mL，锁定时间 8 min）。当患者觉得神经阻滞作用消退时，指示患者独立打开 PCIA，当患者感到剧烈疼痛时，可以按下 PCIA 推注按钮。如果连续 3 次按下 PCIA 推注按钮后数字分级评分法（Numerical Rating Scale，NRS）评分[8]≥4 分，则给予补救镇痛，静脉滴注 50 mg 氟比洛芬酯（北京泰德制药，国药准字 H20041508，5 mL∶50 mg）。

1.3　观察指标　记录两组患者术后 48 h 的反跳痛发生率、疼痛程度以及持续时间。神经阻滞作用消退后手术部位出现的疼痛 NRS 评分≥7 分视为发生反跳痛。记录两组患者术后 6 h、12 h、24 h 及 48 h 的静息 NRS 评分。记录术后 24 h 和 48 h 小腿肌力（采用 Lovett 肌力分级[9]，分为 0~5 级肌力，分别记 0~5 分）；记录 PCIA 首次按压时间、术后 48 h 有效按压次数以及补救镇痛次数；记录不良反应发生情况（如恶心、呕吐和神经阻滞相关不良反应）。嘱患者记录疼痛日记并由专人于术后按时进行随访。

1.4　统计学方法　采用 SPSS 22.0 软件进行统计分析。符合正态分布的计量资料以 $\bar{x}\pm s$ 表示，组间比较采用独立样本 t 检验。偏态分布的计量资料以 $M(P_{25},P_{75})$ 表示，组间比较采用 Mann-Whitney U 秩和检验；多个时间点的重复测量资料组内比较采用 Friedman 检验。计数资料以例（%）表示，采用 χ^2 检验。P<0.05 为差异有统计学意义。

2　结　果

2.1　术后反跳痛发生情况　与高浓度组相比，低浓度组患者术后 48 h 内反跳痛的发生率、NRS 评分较低（P<0.05）。两组患者反跳痛持续时间差异无统计学意义（P>0.05）。见表 2。

2.2　术后静息 NRS 评分比较　两组患者术后 6 h 和 48 h NRS 评分比较差异无统计学意义（P>0.05），术后 12 h NRS 评分高浓度组显著低于低浓度组（P<0.05），而术后 24 h NRS 评分高浓度组显著高于低浓度组（P<0.05）。见表 3。

2.3　术后镇痛相关指标比较　低浓度组术后 PCIA 首次按压时间明显早于高浓度组（P<0.05），而术后 48 h PCIA 有效按压次数及补救镇痛次数明显少于高浓度组（P<0.05）。见表 4。

2.4　术后不良反应和小腿肌力比较　两组患者术后未见神经阻滞相关并发症，且术后 48 h 恶心呕吐发生率和小腿肌力比较差异无统计学意义（P>0.05）。低浓度组术后 24 h 小腿肌力明显强于高浓度组（P<0.05）。见表 5。

表 1　两组患者一般资料比较　（n=44）

Tab.1　Comparison of general data of the two groups　（n=44）

组别	年龄（岁）[a]	性别（男/女）[b]	BMI（kg/m^2）[a]	ASA 分级（Ⅰ/Ⅱ）[b]	骨折类型（双/三踝）[b]	手术侧（左/右）[b]	手术时间（min）[a]	术前 NRS 评分[c]
低浓度组	46.4±15.4	22/22	24.8±3.6	29/15	28/16	19/25	90.3±30.0	2（2，4）
高浓度组	46.3±13.2	25/19	24.0±3.7	26/18	32/12	21/23	87.5±28.1	2（2，4）
$t/\chi^2/Z$ 值	0.022	0.411	1.035	0.436	0.838	0.183	0.455	0.630
P 值	0.982	0.521	0.304	0.509	0.360	0.669	0.651	0.529

注：[a]为数据以 $\bar{x}\pm s$ 表示；[b]为数据以例表示；[c]为数据以 $M(P_{25},P_{75})$ 表示。

表2　两组患者术后48 h反跳痛发生率、疼痛程度及持续时间比较　[n=44, $M(P_{25},P_{75})$]

Tab.2　Comparison of the incidence, pain severity, and duration of rebound pain with in 48 h after surgery between two groups　[n=44, $M(P_{25},P_{75})$]

组别	反跳痛[例(%)]	NRS评分(分)	持续时间(h)
低浓度组	6(13.6)	8(7,9)	3.6(3.1,4.5)
高浓度组	18(40.9)	9(8,10)	3.5(2.7,4.0)
χ^2/Z值	8.250	2.090	0.635
P值	0.004	0.047	0.525

表3　两组患者术后NRS评分比较　[n=44, 分, $M(P_{25},P_{75})$]

Tab.3　Comparison of the postoperative NRS scores between two groups　[n=44, point, $M(P_{25},P_{75})$]

组别	术后6 h	术后12 h	术后24 h	术后48 h	χ^2值	P值
低浓度组	0(0,1)	2(1,3)	3(2,4)	3(2,3)	117.055	<0.001
高浓度组	0(0,0)	1(1,2)	4(3,5)	3(2,4)	122.186	<0.001
Z值	1.187	2.157	2.132	0.138		
P值	0.235	0.031	0.033	0.890		

表4　两组患者术后镇痛相关指标比较　(n=44)

Tab.4　Comparison of the postoperative analgesia indexes between two groups　(n=44)

组别	首次按压时间(min, $\bar{x}\pm s$)	有效按压次数($\bar{x}\pm s$)	补救镇痛次数[$M(P_{25},P_{75})$]
低浓度组	300.6±74.2	15.5±5.0	0(0,1)
高浓度组	623.1±99.8	19.8±7.4	3(1,4)
t/Z值	17.197	3.203	5.261
P值	<0.001	0.002	<0.001

表5　两组患者术后不良反应和小腿肌力比较　(n=44)

Tab.5　Comparison of postoperative adverse reactions and calf muscle strength between two groups　(n=44)

组别	恶心呕吐[例(%)]	小腿肌力[分, $M(P_{25},P_{75})$]	
		术后24 h	术后48 h
低浓度组	22(50.0)	1(1,2)	2(1,3)
高浓度组	19(43.2)	0(0,1)	2(1,3)
χ^2/Z值	0.411	4.313	1.442
P值	0.521	<0.001	0.149

3　讨　论

外周神经阻滞在骨科手术的麻醉和多模式术后镇痛中扮演着关键角色，其优势包括显著减少阿片类药物的使用、更有效地控制术后早期疼痛，以及缩短住院时间等[10-12]。然而，外周神经阻滞消退后出现的反跳痛可能会掩盖外周神经阻滞的益处[13]。踝关节骨折与严重创伤有关，需要术后早期康复训练，因此术后良好的镇痛管理对患者尤为重要[2-3]。本研究选择了双踝或三踝骨折行踝关节骨折切开复位内固定术的患者，踝关节的内侧和外侧由股神经的隐神经分支和坐骨神经独立支配。因此，本团队选择在这里使用收肌管联合腘窝坐骨神经阻滞。

本研究结果显示，高浓度组患者在神经阻滞作用消退后反跳痛的发生率更高、疼痛的严重程度更为明显。由于神经阻滞的作用消退通常发生迅速，表现出快速的“开关”转变[14]，此时血浆中阿片类镇痛药物可能已经完全代谢。因此，当神经阻滞作用突然消退时，通过镇痛泵可能无法及时充分地覆盖神经阻滞作用消退后出现的疼痛，导致反跳痛的出现。

本研究中，与高浓度组相比，低浓度组患者术后12 h NRS评分更高，且术后PCIA首次按压时间明显短于高浓度组，提示在低浓度组中神经阻滞持续时间较短，强度较低。在相同的体积下，高浓度组接受了更高浓度和更大剂量的罗哌卡因，导致神经阻滞持续时间更长。然而，与高浓度组相比，低浓度组患者术后24 h NRS评分显著下降。低浓度组患者术后48 h PCIA有效按压次数及补救镇痛次数明显少于高浓度组，这提示反跳痛的出现增加了术后静脉镇痛药物的使用，与之前的研究结果一致[15]。由于低浓度组神经阻滞持续时间较短，强度较低，促使该组患者更早地开始使用镇痛泵，从而在术后保持一定程度的舒芬太尼血浆浓度。因此低浓度组患者的镇痛可以顺利地从神经阻滞为主的镇痛转变为静脉药物镇痛。

此外，本研究结果显示，低浓度组患者术后24 h小腿肌力较高浓度组患者明显增强，这表明0.125%罗哌卡因对小腿肌力影响较小，从而有利于术后早期运动、早期功能锻炼，对预防术后踝关节粘连有积极作用。多数患者对术后疼痛可接受，但高浓度局麻药周围神经阻滞引起的肢体麻木、运动受限和反跳痛可能会降低患者对周围神经阻滞术后镇痛的总体满意度[16]。

本研究存在一些局限性。首先，只纳入了踝关节骨折患者，需要进一步的临床试验来研究不同浓度局麻药对其他类型神经阻滞和神经阻滞后反跳痛的影响。其次，所有患者在手术过程中都使用了大腿止血带，这可能会加重术后疼痛程度并影响测量精度。最后，本研究仅比较了高浓度和低浓度，有必要扩大样本量，以进一步系统地探索不同浓度梯度的罗哌卡因对反跳痛的影响。

综上所述，在踝关节骨折切开复位内固定术后多模式镇痛中，低浓度罗哌卡因在收肌管联合坐骨神经阻滞作用消退后的反跳痛发生率较低、疼痛程度较轻，且术后阿片类药物消耗较少，对肌力影响更小。

利益冲突　无

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收稿日期:2025-04-29 **修回日期**:2025-07-10 **编辑**:许煜晗

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收稿日期:2025-06-06 **修回日期**:2025-08-02 **编辑**:许煜晗