ORIGINAL PAPER/PŮVODNÍ PRÁCE

Effects of General Anesthesia in Combination with Saphenous Nerve Block-Tibial Nerve Block on Analgesia for Total Knee Arthroplasty and Hemodynamic Indexes

Účinky celkové anestezie v kombinaci s blokádou *n. saphenus* a *n. tibialis* na analgezii u totální artroplastiky kolena a hemodynamické indexy

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Liu D, Wang Y, Tang W. Effects of General Anesthesia in Combination with Saphenous Nerve Block-Tibial Nerve Block on Analgesia for Total Knee Arthroplasty and Hemodynamic Indexes. Acta Chir Orthop Traumatol Cech. 2025;92:85-91.

ABSTRACT

Purpose of the study
We aimed to assess the effects of general anesthesia (GA) plus saphenous nerve block-tibial nerve block (SNB-TNB) on analgesia for total knee arthroplasty (TKA) and hemodynamic indexes.

Material and methods
A control group and an observation group were set for equal allocation of 106 patients with knee osteoarthritis (KOA) treated with TKA during November 2021 and November 2023 through a random number table. GA was used for the control group, and GA plus SNB-TNB was performed for the observation group. Clinical indexes, analgesic effect, joint motion range, hemodynamic indexes and safety were compared between the two groups.

Results
The observation group had decreased fentanyl dosage, patient-controlled intravenous analgesia pump pressing times, morphine dosage, extubation time, and recovery time compared with those of the control group (P<0.05). The static and dynamic Visual Analog Scale scores at different time points were lower in the observation group than in the control group (P<0.05). The observation group had higher maximum flexion degree than that of the control group at different time points (P<0.05). The incidence rate of adverse reactions in the observation group was lower than that of the control group (P<0.05).

Discussion
SNB-TNB can comprehensively intervene with the tissues surrounding the knee joint, and nerve block techniques are capable of intercepting harmful inputs in a targeted manner, elevating pain threshold, inhibiting signaling transmission from nerve endings, and thus terminating the pain perception ability of the cortex. Nerve block mainly depends on local anesthesia, and is helpful for lowering the additional dose of opioids and maintaining the hemodynamic stability.

Conclusions
Compared with simple GA, GA plus SNB-TNB applied in TKA is more conducive to accelerating the recovery of patients, reducing the anesthetic dosage, enhancing the analgesic effect, with more stable hemodynamics and higher safety.

Key words: analgesia, general anesthesia, hemodynamics, nerve block, total knee arthroplasty.

INTRODUCTION

Knee osteoarthritis (KOA) is mainly characterized by degenerative changes in knee joint cartilage, and the sufferers often manifest joint stiffness, limited joint motion, joint pain, *etc.*, seriously affecting their quality of life. As a major treatment means for KOA patients, total knee arthroplasty (TKA) is suitable for patients who have failed conservative treatment, which primarily aims to rebuild the joint system, thereby relieving symptoms and improving the quality of life (15). However, TKA causes large traumas and obvious perioperative pain. Pain can trigger systemic linkage effects, enhance sympathetic excitability, and influence hemodynamic stability, unfavorable for the successful conduction of surgery (6). Moreover, high-quality rehabilitation exercises after TKA are required to rapidly improve knee joint function. Most patients will experience severe pain after TKA, which drastically affects patients' compliance with postoperative rehabilitation exercises (17). Therefore, perioperative analgesia for TKA is not only an important clinical issue to be solved but also a hot topic for clinical research. General anesthesia (GA) boasts such advantages as fast onset and good anesthetic effect, which can ensure a smooth surgery, but its analgesic effect is unsatisfactory (7). With the development of medical technology, nerve block techniques have provided new options for TKA anesthesia, including saphenous nerve block (SNB), tibial nerve block (TNB), and obturator nerve block, which have more significant analgesic effects than GA (3). Nonetheless, simple nerve blocks merely satisfy the demands for local surgical analgesia, so they should be combined with GA in clinical application. Currently, there are few reports about the efficacy of GA plus SNB-TNB in TKA, and most studies focus on the regimen of GA plus SNB.

In view of this, KOA patients undergoing TKA in our hospital over the past 2 years were enrolled to this study to analyze the analgesic effect of GA plus SNB-TNB in TKA and to observe the impact of this regimen on hemodynamics.

MATERIAL AND METHODS

Subjects

A total of 106 patients, who received TKA for KOA in our hospital from November 2021 to November 2023, were selected and grouped in a randomized controlled manner. The control group (n=53) consisted of 36 males and 17 and females aged 37–69 years old, with a mean of (49.95±3.25) years old. The course of disease was 1–4 years and (2.16±1.02) years on average. Besides, there were 20, 15, and 18 cases of American Society of Anesthesiologists (ASA) grades I, II, and III, respectively. Body mass index (BMI) was 20–25 kg/m^2, with a mean of (22.53±1.31) kg/m^2. The observation group (n=53) was set to recruit 39 males and 14 females, whose age was 37–70 years old [(50.01±3.16) years old on average], course of disease ranged from 10 months to 4 years [(2.31±1.14) years on average], and BMI was 20–25 kg/m^2 [average: (22.28±1.24) kg/m^2]. Regarding ASA classification, there were 22 cases of grade I, 16 cases of grade II, and 15 cases of grade III. The general data were comparable between the two groups (P>0.05).

Inclusion and exclusion criteria

Inclusion criteria involved:
1) patients meeting the diagnostic criteria for KOA (2),
2) those with indications of TKA,
3) those with an ASA grade I–III,
4) those with normal coagulation function,
5) those who failed conservative treatment,
6) those treated with surgery for the first time, and
7) those who voluntarily signed the informed consent form.

The exclusion criteria were listed below:
1) patients with comorbid hematological diseases,
2) those with infections in the puncture region,
3) those complicated with chronic paining disease,
4) those with severe anemia,
5) those with cognitive impairment,
6) those with allergy to drugs used in this study,
7) those complicated with systemic infectious diseases,
8) those with congenital knee joint deformity, or
9) those complicated with malignant tumors.

Methods

All patients were deprived of food and water for 8 h before surgery, sent to the operating room to open the venous access, and closely examined by an electrocardiogram monitor for the changes in vital signs.

GA was performed for the control group. Specifically, 0.02 mg/kg midazolam (Jiangsu Nhwa Pharmaceutical Co., Ltd., strength: 2 mL: 10 mg) was injected for sedation, and anesthesia was implemented 5 min later. As for anesthesia induction, 2 μg/kg fentanyl (Yichang Humanwell Pharmaceutical Co., Ltd., strength: 2 mL: 0.1 mg), 2 mg/kg propofol (Xi'an Libang Pharmaceutical Co., Ltd., strength: 10 mL: 0.1 g), and 0.2 mg/kg atracurium (Jiangsu Hengrui Medicine Co., Ltd., strength: 5 mL: 10 mg) were administered *via* intravenous bolus injection, and the patients were connected to the ventilators after muscle relaxation. Regarding the maintenance of anesthesia, 5 mg/(kg.h)$^{-1}$ propofol infusion combined with 2–2.2% sevoflurane (Shanghai Hengrui Medicine Co., Ltd., strength: 120 mL) inhalation was adopted, during which bispectral index (BIS) and fluctuations in heart rate (HR) and mean arterial pressure (MAP) were observed and maintained at 40–60 and about 10% of the baseline values, respectively, by intermittently adding fentanyl and atracurium. Finally, at 10 min before the end of TKA, 12.5 mg of dolasetron (Liaoning HAISCO Pharmaceutical Co., Ltd., strength: 1 mL: 12.5 mg) was infused intravenously.

GA plus SNB-TNB was conducted for the observation group. The specific SNB-TNB method was as follows: The affected lower limb was externally rotated, routinely disinfected and draped. Then an ultrasonic probe was employed to inspect the middle and lower third of the medial thigh, and with the femur found, it was moved to the middle of the sartorius muscle and the adductor muscle to explore the location of the saphenous nerve, which was subsequently punctured by means of ultrasound-guided in-plane needle insertion. When blood backflow was not observed during retraction, 10 mL of 0.3% ropivacaine (Qilu Pharmaceutical, strength: 10 mL: 75 mg) was injected, and the diffusion of the drug was observed. Next, the needle was inserted 20 min later to observe the block effect. After the onset of SNB, the affected limb was slightly flexed and lifted to expose the posterior thigh, followed by routine disinfection, draping, and ultrasonic scanning of the popliteal fossa. Later, the sciatic nerve was distinguished as the tibial nerve and the common peroneal nerve branches, with the former as the target of puncture. The needle insertion method was the same as that for SNB, and 10 mL of 0.5% ropivacaine was injected when no blood backflow was observed. Finally, GA was performed following successful SNB-TNB in the same way as that in the control group.

For both groups, tourniquets were used for 60 min at the beginning of TKA. Patient-controlled intravenous analgesia (PCIA) was carried out after surgery for both groups, with supplementation of 0.05 mg/kg morphine hydrochloride injection (Shenyang No. 1 Pharmaceutical Co., Ltd., Northeast Pharmaceutical Group, strength: 5 mL: 10 mg), no background dosage, and lockout time of 10 min. The patients pressed the PCIA pump on their own when the Visual Analog Scale (VAS) score was >4 points, so as to enhance the postoperative analgesic effect.

Evaluation of outcomes

(1) Clinical indexes: The fentanyl dosage, PCIA pump pressing times, morphine dosage, extubation time and recovery time were compared between the two groups.

(2) Analgesic effect: VAS score (10 points in total) was applied to assess the severity of static and dynamic pain in the two groups at 6, 12, 24, and 48 h after surgery (20), which was divided into 0 (none), 1–3 (mild), 4–6 (moderate), and 7–10 (severe) points, and a higher score indicated severer pain.

(3) Joint motion range: X-ray films of the knee joints in the extension and maximum passive flexion positions were shot for the two groups at 24 h, 48 h, 72 h and 1 week after surgery, and the maximum flexion degree was measured. Within a reasonable range, the greater the flexion degree was, the better the joint motion range would be.

(4) Hemodynamics: HR and MAP of the two groups of patients were recorded at three time points: before anesthesia (T_0), at the time of skin incision (T_1), and at the time of extubation (T_2). Smaller fluctuations within the normal ranges denoted more stable hemodynamics.

(5) Adverse reactions: The occurrence of postoperative nausea, vomiting, respiratory depression, agitation, and hypoxemia in both groups was recorded.

Statistical analysis

SPSS 23.0 software was utilized for statistical analysis. Measurement data were expressed by mean ± standard deviation ($\bar{x} \pm s$) and subjected to the independent-samples *t*-test. Count data were described as percentage [n (%)] and compared by the χ^2 test. P<0.05 denoted a statistically significant difference.

RESULTS

Clinical indicators

The observation group had decreased fentanyl dosage, PCIA pump pressing times, morphine dosage, extubation time, and recovery time compared with those of the control group (P<0.05) (Table 1).

Analgesic effect

The static and dynamic VAS scores at different time points were lower in the observation group than those in the control group (P<0.05) (Table 2).

Table 1. **Clinical indexes (x ± s)**

GROUP	FENTANYL DOSAGE (mg)	PCIA PUMP PRESSING TIMES (times)	MORPHINE DOSAGE (mg)	EXTUBATION TIME (min)	RECOVERY TIME (min)
Control (n=53)	0.29±0.12	6.95±2.10	13.56±2.11	16.95±4.02	11.65±1.72
Observation (n=53)	0.13±0.05	4.12±1.14	9.12±1.33	10.32±2.56	7.43±1.03
t	8.960	8.622	12.960	10.128	15.324
P	<0.001	<0.001	<0.001	<0.001	<0.001

Table 2. **Analgesic effect (x ± s, point)**

GROUP	STATIC				DYNAMIC			
	6 h after surgery	12 h after surgery	24 h after surgery	48 h after surgery	6 h after surgery	12 h after surgery	24 h after surgery	48 h after surgery
Control (n=53)	3.17±0.25	3.05±0.41	2.86±0.37*	1.63±0.30*	3.35±0.26	3.22±0.58	2.90±0.43*	2.19±0.25*
Observation (n=53)	2.28±0.30	2.39±0.36	2.03±0.28*	1.27±0.22*	2.38±0.20	2.45±0.37	2.10±0.32*	1.60±0.26*
t	16.592	8.806	13.023	7.045	21.528	8.148	10.866	11.908
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

*P<0.05 *vs.* 6 h after surgery within the group.

Table 3. **Joint motion range (x ± s)**

GROUP	24 h AFTER SURGERY	48 h AFTER SURGERY	72 h AFTER SURGERY	1 WEEK AFTER SURGERY
Control (n=53)	48.12±5.10	56.35±2.78	67.53±3.05	88.49±5.33
Observation (n=53)	51.53±3.43	61.29±3.14	73.25±2.61	93.56±3.72
t	4.039	8.575	10.374	5.679
P	<0.001	<0.001	<0.001	<0.001

Table 4. **Hemodynamics (x ± s)**

GROUP	HR (beats/min)			MAP (mm Hg)		
	T_0	T_1	T_2	T_0	T_1	T_2
Control (n=53)	75.89±5.83	58.56±4.15*	74.25±5.33	104.36±6.34	83.16±6.08*	104.98±6.22
Observation (n=53)	75.25±5.91	62.35±3.80*	76.02±6.16	104.44±6.29	87.43±7.14*	104.86±7.11
t	0.561	4.904	1.582	0.065	3.315	0.093
P	0.576	<0.001	0.117	0.948	0.001	0.927

T_0: Before anesthesia; T_1: at the time of skin incision; T_2: at the time of extubation. *P<0.05 vs. T0 within the group.

Table 5. **Adverse reactions [n (%)]**

GROUP	NAUSEA	VOMITING	RESPIRATORY DEPRESSION	AGITATION	HYPOXEMIA	TOTAL INCIDENCE RATE
Control (n=53)	3 (5.66)	1 (1.89)	1 (1.89)	2 (3.77)	1 (1.89)	8 (15.09)
Observation (n=53)	1 (1.89)	0 (0.00)	0 (0.00)	1 (1.89)	0 (0.00)	2 (3.77)
χ^2						3.975
P						0.046

Joint motion range

The observation group presented higher maximum flexion degree than that of the control group at different time points (P<0.05) (Table 3).

Hemodynamics

HR and MAP at T_0 were comparable between the two groups, with no statistically significant differences (P>0.05). HR and MAP were reduced at T_1 in comparison to those at T_0 in both groups, but they were higher in the observation group than those in the control group (P<0.05). Similar HR and MAP were detected at T_2 and T_0 in both groups, showing no statistically significant differences (P>0.05) (Table 4).

Adverse reactions

The incidence rate of adverse reactions in the observation group was lower than that of the control group (P<0.05) (Table 5).

DISCUSSION

According to epidemiological statistics, KOA frequently occurs in middle-aged and elderly people, and its incidence rate is on the rise with the exacerbated population aging in China (9). Diversified treatment methods for KOA have emerged as medical technology is developing, and patients who have received unsatisfactory drug treatments can also choose surgical treatment. TKA has become the mainstream procedure for treating KOA, and the replacement of damaged knee joint can prominently ameliorate the knee joint function and facilitate the recovery of motor function. However, TKA may cause great damage to the body, trigger severe pain, and even chronic pain in some patients, which is not conducive to postoperative rehabilitation. The pain after TKA stimulates nervous excitation, increases the body's oxygen consumption, and tends to induce hypoxemia, resulting in unstable vital signs (4). Pain, known as the fifth most important vital sign, can also serve as a protective mechanism while bringing harm, which has attracted much attention in the field of surgery. Therefore, the selection of safe and efficient analgesia and anesthesia regimens is a key issue to be solved urgently in clinic.

The anesthetic methods for TKA, anesthetic drugs, and perioperative vital signs are essential factors affecting the postoperative recovery of patients. As an extensively applied anesthetic method in various types of surgery, GA boasts the advantages of simple operation and fast onset and is able to maintain a stable depth of anesthesia, but the analgesia mainly relies on opioids (14). Although opioids have obvious analgesic effects, their overdose can induce a variety of adverse reactions and influence the safety of surgery, so there are certain limitations in the analgesic effect of GA. The ideal analgesic mode for TKA should not only alleviate pain and avoid the impact of pain on joint motion, but also refrain from the overdose of opioids and improve the safety. In recent years, nerve block techniques have taken a place in surgery and been classified as targeted anesthesia. Through the injection of local anesthetic drugs, such techniques can rapidly act on the nerve tissues and efficiently exert the analgesic effect *via* accurate positioning under ultrasound guidance and high safety (18). The knee joint is mainly innervated by the obturator and femoral nerves, followed by the sciatic nerve, so femoral nerve block (FNB) and sciatic nerve block are generally adopted for TKA-treated patients. Nonetheless, the operations of FNB and sciatic nerve block are likely to decrease the muscle strength of quadriceps femoris and lower limbs, thus affecting early recovery (5). Since the saphenous nerve and tibial nerve are branches of the femoral nerve and sciatic nerve, respectively, the gradual substitution of FNB and sciatic nerve block with SNB and TNB can achieve similar analgesic effects without affecting the muscle strength (12). The analgesic effect of multi-nerve block on the nerves innervating the knee joint is superior to that on single nerve block (19). Currently, multimodal analgesia is recommended in clinical practice, and the combination with analgesic regimens can reduce the dose of a single anesthetic drug and exert a synergistic effect. It was revealed in this study that the fentanyl dosage, PCIA pump pressing times, morphine dosage, extubation time, recovery time, and static and dynamic VAS scores at different time points were decreased in the observation group compared to those in the control group, suggesting that GA plus SNB-TNB can reduce the dose of analgesic drugs, promote rapid recovery of physiological function after surgery, and improve the postoperative analgesic effect. Li *et al.* (11) reported that SNB-TNB applied in combination with GA to KOA resulted in a good analgesic effect, stable hemodynamics, low-level inflammatory responses, and high safety, supporting the above results obtained from this study. The reason is that as the terminal branch of the femoral nerve, the saphenous nerve is the longest cutaneous nerve in the body, which is only responsible for sensation and innervates the anteromedial, medial, and posteromedial lower limbs. The tibial nerve, located at the top layer of the popliteal fossa, arises from the sciatic nerve and mainly innervates the posterior lower leg (1). SNB-TNB can comprehensively intervene in the tissues surrounding the knee joint, and nerve block techniques are capable of intercepting harmful inputs in a targeted manner, elevating pain threshold, inhibiting signaling transmission from nerve endings, and thus terminating the pain perception ability of the cortex (8). Therefore, the application of SNB-TNB based on GA can reduce the dose of opioids, promote the postoperative recovery of physiological function as soon as possible, and enhance the analgesic effect.

About 30–60% of patients suffer from limited joint motion due to pain after TKA and produce fear of postoperative rehabilitation exercises, which directly affects the rehabilitation effect (10). In this study, the maximum flexion degree at different time points was higher in the observation group than that in the control group, implying that such an anesthesia regimen in TKA helps to improve the joint motion range as early as possible. It is possibly because GA plus SNB-TNB has a prominent analgesic effect, which can avoid the resistance to postoperative rehabilitation exercises due to pain, laying a good foundation for early rehabilitation exercises after surgery and facilitating the improvement of joint motion range. On the other hand, the saphenous nerve is solely responsible for sensation, without motor components, and the tibial nerve has no impact on the muscle strength of the lower limbs, which promotes the quick recovery of muscle strength after surgery and facilitates the improvement in joint motion range (16). In addition, surgical operation, anesthetic drug dose, intubation, and extubation will stimulate the organisms to a certain extent and cause hemodynamic fluctuations, thereby affecting surgical effect. As revealed in this study, the fluctuations in HR and MAP at T_0, T_1 and T_2, as well as the incidence rate of adverse reactions, were decreased in the observation group by contrast to those in the control group, suggesting that GA plus SNB-TNB is conducive to reducing the fluctuations in hemodynamic indexes, with higher safety. The reason is that nerve block mainly depends on local anesthesia, and is helpful for lowering the additional dose of opioids and maintaining the hemodynamic stability. The overuse of opioids is prone to induce respiratory depression, nausea, vomiting and other adverse reactions, so the reduction of opioid dose can improve safety to a certain extent (22).

In addition to the interventions studied herein, it is important to note other widely recommended pain-reducing procedures. Spinal anesthesia is favored over GA according to the consensus reached by experts at the World Expert Meeting in Arthroplasty, due to its advantages in minimizing postoperative pain and enhancing recovery (13). Furthermore, the administration of local infiltration anesthesia has also been recommended as an effective method for relieving pain, with the added benefit of lowering opioid consumption and maintaining hemodynamic stability (21). Although this study focuses on different aspects of postoperative care, acknowledging these alternative pain management strategies provides a broader context for improving the outcomes.

CONCLUSIONS

In conclusion, as for TKA, GA plus SNB-TNB is more objective than simple GA in terms of clinical indexes, which can effectively improve the analgesic effect, ameliorate the joint motion range, and maintain hemodynamic stability, presenting high safety. ■

Abbreviations

FNB – femoral nerve block
GA – general anesthesia
KOA – knee osteoarthritis
PCIA – patient-controlled intravenous analgesia
SNB – saphenous nerve block
TKA – total knee arthroplasty
TNB – tibial nerve block
VAS – Visual Analog Scale

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