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ORIGINAL RESEARCH ARTICLE

Comparison of nerve block and spinal anesthesia in second toe pulp free flap surgery for fingertip reconstruction

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ABSTRACT

Toe pulp flap surgery is a viable option for soft tissue defects of the fingertips, effectively addressing patient needs and fingertip characteristics. The preferred anesthesia for lower-extremity surgery includes spinal and regional anesthesia. However, the choice between these methods depends on patient safety and surgical efficacy. In this retrospective study, we aimed to ascertain the optimal anesthetic technique by examining the efficacy, safety, pain control, and potential side effects of spinal and peripheral nerve block anesthetics. We included 40 patients aged 18–60 years who underwent partial second toe pulp free flap surgery for fingertip reconstruction. Twenty patients received spinal anesthesia (SA), while the remaining 20 received peripheral nerve block anesthesia. We conducted a comparative analysis of postoperative pain scores, adverse effects, analgesic usage, and patient satisfaction scores associated with each anesthesia method. Independent t-test, Mann–Whitney U test, and chi-squared test were performed. The SA group exhibited hypotension, bradycardia, urinary retention, and postdural puncture headache rates of 10%, 10%, 5%, and 5%, respectively. A significant difference in the timing of first analgesic use was observed (spinal, 3.7 ± 0.8 vs. peripheral nerve block, 13.2 ± 6.6; $P = 0.006$). Visual analog scale (VAS) scores of the patients at the 2nd, 4th, and 6th h were significantly lower in the peripheral nerve block group ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively). VAS scores at 12 and 24 h were similar between the groups ($P = 0.07$, $P = 0.135$, respectively). Peripheral nerve block anesthesia is superior to SA for partial second toe pulp free flap surgery, offering lower complication rates, reduced postoperative pain, and improved patient comfort.

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Introduction

Fingertip amputation is one of the most prevalent injuries in daily life [1]. Numerous factors contribute to a high incidence of fingertip injuries. Handling sharp tools or operating machinery is the primary cause of fingertip injury. Moreover, injuries can result from pinching or pressing fingertips with heavy objects or doors. Such accidents are particularly prone to occur in hazardous work environments or in confined spaces [2]. In situations where a finger is completely or partially amputated, replantation is generally the primary treatment option [3]. However, the success of replantation is technically demanding.

When aiming to maximize finger preservation while considering both function and aesthetic restoration, the 'toe pulp free flap' technique is one of the most suitable choices [4].

In toe pulp free flap surgery, anesthesia of the toes is essential. Two main methods are commonly employed for performing toe anesthesia: spinal anesthesia (SA) and popliteal sciatic nerve block (PSNB).

SA involves injecting an anesthetic into the lower back to induce numbness in the lower body and sustain insensitivity throughout the toes, rendering it well suited for toe surgeries. PSNB, categorized under regional anesthesia, targets the posterior side of the knee, anesthetizes the sciatic nerve, and results in numbness in the lower body, making it suitable for toe surgery.

The choice between these methods depends on patient safety and surgical efficacy. Thus, the objective of this study was to select the most appropriate anesthetic method to ensure patient safety and optimal surgical outcomes.

Surgeons face difficulties in deciding between SA and PSNB when performing toe pulp free flap surgery [5]. Considering this, we evaluated comparative studies on the two anesthesia methods in similar surgeries [6–8]. In a study by Lee et al., in the field of ankle and foot surgery, it was demonstrated that SA resulted in a shorter procedure duration and shorter onset and duration of sensory and motor blocks. Furthermore, patients receiving SA had higher postoperative analgesic demands than those receiving PSNB, and their systolic blood pressure was lower within 30 min after surgery. According to Sugathan et al., the effect of a femoropopliteal block in ankle surgery is slower to manifest, but it significantly reduces opioid consumption during the postoperative period, providing effective pain management [7]. Furthermore, based on the research by Jeon et al., in hallux valgus surgery, despite longer surgical times, PSNB is safe and provides adequate anesthesia levels, allowing for effective pain management and reduced side effects after surgery [9]. Consequently,

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PSNB is considered a promising anesthetic technique for hallux valgus surgeries.

Anesthetic techniques have been extensively studied across various surgical fields to enhance patient safety and surgical outcomes [9, 10]. However, research on these two anesthesia techniques in hand surgery is limited because of specific circumstances. This unique situation arises because foot anesthesia is primarily considered in the context of hand reconstructive surgery, leading to a lack of comparative studies on the optimal method for foot anesthesia.

Utilization of foot tissue for hand reconstructive surgery is an important therapeutic approach for improving patients' quality of life and facilitating functional recovery. When considering foot anesthesia, it is crucial to thoroughly evaluate the effectiveness and safety of this technique to select the most suitable anesthesia method for individual patients.

In this study, we aimed to compare the potential adverse effects, postoperative pain levels, utilization of pain-relieving medications, and patient satisfaction scores among individuals who underwent a second toe pulp free flap surgery with the choice between PSNB or SA. Through this investigation, we endeavor to offer valuable insights that could further improve the safety and comfort of the surgical experience of patients undergoing hand surgery.

Materials and methods

Patient selection

In this retrospective study, conducted between March 2020 and March 2022, we enrolled 40 patients aged 18–60 years who underwent partial second toe pulp free flap surgery for fingertip injuries. The inclusion criteria were defined as follows: patients requiring reconstruction with a defect size of 2.5 × 1.5 cm or less, either due to necrosis following digit replantation or soft tissue damage due to finger injuries. Additionally, we specifically focused on patients with an American Society of Anesthesiologists (ASA) physical status score of 1 or 2. Twenty patients underwent SA, whereas the remaining 20 underwent PSNB. We aimed to match several parameters, including the duration of anesthetic intervention, surgery initiation time, anesthetic efficacy, and adverse effects, between the two groups. Patient demographics were similar between groups (Table 1).

Method of ultrasonographic guided nerve block

Patients in the PSNB group (n = 20) underwent sciatic and saphenous nerve blocks under ultrasonographic guidance. The procedure was performed by using a 26-G peripheral block needle. Among the local anesthetics, ropivacaine, known for its prolonged duration of anesthesia, was chosen for its selective blockage of sensory nerves and limited adverse effects on the cardiovascular and central nervous systems [11].

After lateral positioning, ultrasonography was used to locate the popliteal artery in the popliteal fossa. The probe was then moved proximally along the popliteal artery to determine the point where the tibial and popliteal nerves converged to form the sciatic nerve. Subsequently, the needle was inserted from the posterolateral side using the in-plane technique, and the needle tip was placed in the epineurium. To ensure that the blood reflux was not directly injected into the blood vessel, 15 ml of 0.75% ropivacaine was injected in a circular shape around the nerve.

We performed a saphenous nerve block to reduce calf tourniquet pain. The patient assumed a frog-leg position while in a supine posture. A nerve block was performed by locating the saphenous nerve between the sartorius and gracilis muscles under ultrasound guidance. The nerve was located immediately before passing through the fascia lata of the medial condyle of the tibia. At this anatomical level the saphenous nerve visualized using ultrasonography, was confirmed to be hyperechoic between the two tendons. The needle tip was positioned between these two tendons, and a meticulous check for blood reflux was conducted. Subsequently, 10 ml of 0.75% ropivacaine was administered using the in-plane technique.

Surgical technique

We used brachial plexus block and SA- or ultrasonography-guided popliteal sciatic and saphenous nerve blocks for the surgical procedure. The operation was performed under tourniquet control with a moderate amount of exsanguination to preserve visibility of the small volar digital veins. Subsequently, a flap harvest was performed, which included the pulp, skin, vein, digital artery, and nerves. The vessels were anastomosed to the digital artery and volar veins of the recipient [4].

Assessment of anesthesia

This was evaluated through retrospective medical record analysis. Patients' pain and satisfaction assessments were routinely conducted. At 5-min intervals, the hemodynamic parameters of the patients in both groups were measured and recorded. A dose of 30 mg ketorolac was administered to each patient every 12 h via the intramuscular route for 2 days following surgery. To address additional analgesic requirements, tramadol hydrochloride (1 mg/kg) was administered intramuscularly. Pain scores on the visual analog scale (VAS) were assessed for both groups at the 2nd, 4th, 6th, 12th, and 24th h after anesthetic intervention. Postoperative adverse effects, including urinary retention, urinary catheterization, and postdural puncture headache (PDPH), were recorded. Patients experiencing PDPHs received acetaminophen tablets with caffeine once every 6 h, along with appropriate hydration. All patients were treated successfully, and none of them required epidural blood patch treatment. Foot drop examinations were conducted once every 24 h. Two weeks after surgery, patients without any complications were discharged. On

Table 1. Patient demographic data.

	Spinal group (N = 20)	Nerve block group (N = 20)	P
Age (year)	55.5 ± 4.9	52.5 ± 10.3	0.133
Sex (M/F)	17 / 3	16 / 4	0.429
Height (cm)	169.8 ± 7.2	169.6 ± 5.9	0.943
Weight (kg)	67.9 ± 8.5	66.6 ± 8.1	0.636
HTN (N/Y)	10 / 10	6 / 14	0.197
DM (N/Y)	11 / 9	13 / 7	0.519
Cardiovascular disease (N/Y)	18 / 2	14 / 6	0.114
Injured finger (Index / Long / Ring / Little)	12 / 5 / 2 / 1	9 / 5 / 5 / 1	-

HTN: hypertension; DM: diabetes.

Table 2. Patient anesthetic and surgery data.

	Spinal group ($N = 20$)	Nerve block group ($N = 20$)	P
Surgery initiation time (min)	6.6 ± 1.1	23.6 ± 6.6	<0.001
Duration of anesthesia (hour)	5 ± 4.0	11.1 ± 1.4	<0.001
Duration of surgery (min)	63.8 ± 5.8	61.4 ± 5.08	0.173
Revision (number)	2	1	0.636
Timing of first analgesic use (h)	3.7 ± 0.8	13.2 ± 6.6	0.006
Hypotension (number)	2	0	-
Bradycardia (number)	2	0	-
PDPH (number)	1	0	-
Urinary retention (number)	1	0	-
Persistent numbness(number)	0	0	-

PDPH: postdural puncture headache.

postoperative day 1, the patients were surveyed regarding their physical comfort, emotional state, psychological support, and physical independence using the Korean version of the quality of recovery-15 questionnaire (QoR-15K) [12].

Statistical methods

All analyses were performed using SPSS version 28 (IBM Corp., Armonk, N.Y., USA). Continuous variables were analyzed using the independent t-test or Mann–Whitney U test, and categorical variables were analyzed using the chi-squared test. Statistical significance was set at $P \leq 0.05$.

Ethics

This study conforms to the Declaration of Helsinki ethical principles for medical research. This study was approved by the IRB (IRB No. 2022-07-033).

Results

No significant differences in demographic factors were observed between the two groups (Table 1). Following anesthesia, the initiation time for surgery was significantly shorter in the SA group ($P < 0.001$). Patients in the SA group exhibited hypotension, bradycardia, urinary retention, and PDPH rates of 10%, 10%, 5%, and 5%, respectively. No adverse events were observed in the PSNB group. A statistically significant difference was observed in the timing of postoperative first analgesic use (SA, 3.7 ± 0.8 vs. PSNB, 13.2 ± 6.6, $P = 0.006$) (Table 2). Moreover, the VAS scores of the patients were significantly lower at the 2nd, 4th, and 6th h in the PSNB group ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively). At the 12th and 24th h, the VAS scores did not differ significantly between the groups ($P = 0.07$, $P = 0.135$, respectively). Patient satisfaction with QoR-15K was markedly higher in the PSNB group ($P = 0.002$) (Table 3).

Discussion

Ultrasound-guided regional nerve block for lower-extremity surgery is easy and convenient. It is safer than general anesthesia and SA for orthopedic surgery [7, 13–15]. Thus, its usage has become increasingly popular. Peripheral nerve block has emerged as a feasible alternative to SA for partial second toe pulp free flap surgeries. This is attributed not only to reduced complication rates and enhanced postoperative pain management but also to increased patient satisfaction. In this study, we determined that PSNB offered extended and more efficacious analgesia than did SA. In the PSNB group, both VAS and QoR-15K scores were superior to those in the SA group. In particular, it was superior in terms of postoperative pain, which usually lasted approximately 12 h after nerve block, allowing the patient to be free from pain for a longer period. (11.1 ± 1.4 vs. 2.4 ± 0.5, respectively, $P < 0.001$). Similar to previous studies, peripheral nerve blocks yielded prolonged analgesic effects and enhanced patient satisfaction [7, 14, 15].

However, nerve blocks have the disadvantage of rebound pain [16]. Although the cause has not yet been elucidated in detail, three main reasons have been proposed. The first is abnormal spontaneous C-fiber activity and hyperexcitability of nociceptors after nerve block [17]. These nerve changes cause symptoms of transient heat hyperalgesia in patients; however, no evidence has been found of altered sensory thresholds or nerve lesions in animal experiments [18]. Second, the type of surgery and changes in the nerve are caused by anesthesia during the nerve block. The frequency or intensity of rebound pain varies depending on the type of surgery performed. It occurs more frequently in bone surgery than in soft tissue surgery, and its intensity is stronger in shoulder surgery than in complex knee surgery [16, 19, 20]. Local anesthetics are neurotoxic, which is an intrinsic pro-inflammatory property thought to create a transient hyperalgesic state. Therefore, various attempts have been made to reduce inflammation by using substances such as clonidine, buprenorphine, and dexamethasone [21]. Finally, as a patient characteristic, rebound pain is more commonly observed in women, younger patients (20–60 years old), and those with severe preoperative pain [22–24]. In this study, although only young and healthy patients were included, there were a few cases of severe rebound pain. This can be attributed to soft tissue surgery, most of which was performed in men, and patient education regarding the possibility of a burning sensation approximately 8–14 h after the regional block. This may have reduced rebound pain in this study. Our study was limited to healthy individuals with an ASA physical status score of I–II, designed for patients capable of accurately expressing their pain responses. However, when considering older adults or hemodynamically unstable patients, the advantages of nerve blocks are believed to be more evident.

Another crucial factor to consider when selecting an anesthetic method is patient consent and satisfaction. The emotional state and psychological support scores were elevated in the PSNB group because the peripheral nerve block resulted in less postoperative pain and eliminated the need to maintain bed rest for 4 h after surgery compared with SA. We found surgery initiation times (nerve block:

Table 3. Patient VAS and QoR-15K data.

	Spinal group ($N = 20$)	Nerve block group ($N = 20$)	P
VAS 2 hour	5.1 ± 1.7	0.6 ± 0.7	<0.001
VAS 4 hour	4.7 ± 1.6	1.1 ± 1.0	<0.001
VAS 6 hour	4.15 ± 1.0	2.5 ± 0.9	<0.001
VAS 12 hour	3.45 ± 0.6	4.0 ± 1.2	0.07
VAS 24 hour	2.55 ± 1.0	3.0 ± 0.0	0.135
QoR-15K	73.6 ± 11.8	83.7 ± 6.5	0.002

VAS: Visual Analogue Scale; QoR-15K: Korean version of the Quality of Recovery-15.

23.5 min ± 6.6 vs. spinal: 6.6 min ± 1.1, $P < 0.001$) to be notably extended in the PSNB group. Longer intervention time with nerve blocks may be a potential disadvantage. However, since the duration of anesthesia is long, preparing for anesthesia in advance can save time in preparation for surgery. As motor nerve anesthesia is not performed immediately after nerve block, there are few restrictions on patient transport. However, transportation following an SA may pose risks to patient safety. Typically, anesthesiologists are advised to conduct SA in the operating room to mitigate the risk of falls. Therefore, the preparation time for surgery can be reduced using nerve blocks. These features likely ensure a better and more effective use of the operating room in patients undergoing surgery with PSNB.

In addition to the advantages of peripheral nerve blocks, complications such as direct nerve injury, local hematoma, subsequent ischemic injury, infection, inefficient block, and systemic toxicity following vascular injection may occur with peripheral nerve blocks, but these rarely occur under ultrasound guidance [25]. We did not observe these complications in our study, and only a few patients complained of numbness, all of whom showed spontaneous improvement.

This study had several limitations. First, it was a retrospective study. Second, only healthy participants were included in this study. However, this study highlights the merits of nerve block surgery through additional research involving older adult patient groups. Third, multimodal approaches have not been used to prevent rebound pain. As this was only a soft tissue surgery, the use of analgesics was deemed more reasonable for patients experiencing pain after nerve block rather than using various medications.

In conclusion, we found that peripheral nerve block is a feasible alternative to SA for partial second toe pulp free flap surgeries. Nerve block is preferable to SA because of lower complication rates, postoperative pain, and enhanced patient comfort. A clear disadvantage of nerve blocks is the longer intervention duration, which can be resolved by performing the procedure before entering the operating room.

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Disclosure statement

The authors report there are no competing interests to declare.

Data availability statement

The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

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