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ORIGINAL ARTICLE

The role of electrical stimulation in ultrasound-guided subgluteal sciatic nerve block: a retrospective study on how response pattern and minimal evoked current affect the resultant blockade

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Abstract
Purpose Nerve stimulation may be combined with ultrasound imaging for a block of deeply located nerves such as the sciatic nerve in the subgluteal region. At present, it is unknown how the use of nerve stimulation affects blockade after this nerve block. We retrospectively compared the effects of the two types of motor response and those of minimal evoked current above and below 0.5 mA on ultrasound-guided subgluteal sciatic nerve block using mepivacaine or ropivacaine, two local anesthetics with different onset time and duration.
Methods We reviewed records and video images of patients who, from April 2008 until October 2011, received ultrasound-guided subgluteal sciatic nerve block combined with nerve stimulation using 20 ml of either 1.5 % mepivacaine with 1:400,000 epinephrine or 0.5 % ropivacaine. Sensory and motor blockade data for 30 min after the block and for the duration of the blockade were gathered. Patients for whom any data were missing, the video image was poor, and/or intraneural injection was observed during the block were excluded from the study. The same data were compared in two ways: regarding the motor response pattern between the response of the tibial nerve and the common peroneal nerve, and regarding the minimal current between low current ($<$ 0.5 mA) and high current ($\geq$0.5 mA). The primary endpoints were the onset and duration of blockade of the sciatic nerve block.
Results We analyzed the data of 170 and 99 patients who received mepivacaine and ropivacaine, respectively. The progress of sensory and motor blockade as well as block duration was similar between different motor response patterns after both anesthetics. The proportion of patients who developed sensory block of the tibial nerve and motor block at 30 min was higher in the low minimal current group than in the other group receiving mepivacaine. Patients in the former group also had longer block duration. With ropivacaine, complete motor blockade was present at 30 min in a higher proportion of patients after lower minimal evoked current than after higher minimal evoked current.
Conclusion When ultrasound-guided subgluteal sciatic nerve block was conducted with nerve stimulation, the motor response pattern did not markedly affect the progress of sensory or motor blockade or block duration. Lower minimal evoked current was associated with faster onset in sensory and motor block and longer block duration after mepivacaine and faster onset in motor block after ropivacaine. The clinical significance of this, however, has yet to be determined.

Keywords Nerve block · Sciatic nerve · Ultrasonography · Nerve stimulation

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Introduction

Sciatic nerve block in the subgluteal region provides anesthesia and/or analgesia in patients undergoing various surgical procedures in the lower extremities. Development of ultrasound imaging allows direct visualization of nerve structures and real-time needle guidance to the target in some peripheral nerve blocks. Previous clinical studies have shown higher success rates of those blocks with ultrasound imaging [1–3]. However, the sciatic nerve is deeply located in the subgluteal region, and thus the insertion angle of the needle can be very steep, making visualization less than optimal for both the nerve and needle. The nerve stimulation technique may be combined to help perform ultrasound-guided subgluteal sciatic nerve block. Nerve stimulation of the sciatic nerve can elicit two types of motor response: response of the tibial nerve and response of the common peroneal nerve. The type of evoked motor response should reflect the needle tip position relative to respective nerves and thus may determine progress and quality of the blockade obtained [4, 5]. To date, however, the two types of response have not been compared when ultrasound imaging is used to perform sciatic nerve block. In addition, the intensity of minimal current at which sciatic nerve stimulation is achieved may reflect the needle–nerve distance and thus could be another important factor affecting the quality of the resultant blockade. However, the effects of minimal current to elicit motor response on the blockade produced with this block technique have yet to be studied.

Although the needle tip is often repositioned to produce circumferential spread of an anesthetic solution under ultrasound guidance [6], the injection starts when nerve stimulation is used. We hypothesized that differences in motor response pattern and minimal evoked current might result in some differences in sensory and motor blockade.

Therefore, by using data collected and stored in our operating room information system, we compared the effects of the two types of motor response to sciatic nerve stimulation and minimal evoked current above and below 0.5 mA on ultrasound-guided subgluteal sciatic nerve block. Because we clinically use both short- and long-acting local anesthetics for peripheral nerve blocks, sensory and motor blockade after two different local anesthetics, mepivacaine and ropivacaine, was analyzed in the present study.

Methods

After receiving ethics committee approval at Shimane University School of Medicine (Izumo City, Japan), we reviewed data obtained from patients of American Society of Anesthesiologists physical status 1 or 2 who received ultrasound-guided sciatic nerve block combined with nerve stimulation between April 2008 and October 2011 for arthroscopic knee surgery [anterior cruciate ligament (ACL) reconstruction, meniscectomy, and meniscal repair]. All the data had been collected and stored in our operating room information system: these data included anesthesia and block records and ultrasound video images. The present study was retrospectively conducted using data from patients of whom most were recruited for different prospective studies [7–9]. Therefore, we did not obtain written informed consent from each patient to participate in the present study. No patient had a history of diabetes mellitus or neurological disease or required general anesthesia before any nerve block.

In the operating room, standard noninvasive monitors including continuous electrocardiogram, blood pressure, and pulse oximetry were set up, and an IV infusion of acetated Ringer's solution was started for each patient. All patients received fentanyl 50–100 µg and midazolam 1–2 mg intravenously for anxiolysis, while remaining responsive to verbal cues.

The subgluteal approach to the sciatic nerve block was conducted with patients in the semiprone position with the side to be anesthetized uppermost. A low-frequency, 5–2 MHz, curved array transducer (MicroMaxx or M-Turbo Ultrasound System; Sonosite, Bothell, WA, USA) was positioned perpendicular to the skin on the line connecting the ischial tuberosity and greater trochanter. The location was scanned until a clear transverse image of the hyperechoic sciatic nerve between the ischial tuberosity and greater trochanter was obtained. After skin sterilization with an iodine solution and skin infiltration with 1 % mepivacaine, a short-bevel 100-mm, 21-gauge insulated nerve block needle (CCR; Hakko, Chikuma, Japan) connected to a nerve stimulator (Braun, Melsungen, Germany) was inserted parallel and in line with the ultrasound transducer, which was covered with a sterile plastic cover and gel, from posterolateral to anteromedial. While keeping the sciatic nerve in the middle of the ultrasound screen, the needle was advanced slowly until it was immediately adjacent to the nerve. Then, a nerve stimulator set at 1.0 mA with pulse duration of 0.1 ms and stimulating frequency of 2 Hz was turned on to elicit foot plantarflexion or dorsiflexion. When the response was observed, the current was gradually reduced to obtain minimal evoked current eliciting the motor response. If the response was not evoked at 1.0 mA, the needle was adjusted until the foot movement was observed. Once the minimal evoked current was established, nerve stimulation was switched off, and no attempt was made to seek an even smaller electric current to elicit motor response or a particular motor response pattern. A local anesthetic solution of 20 ml was then injected incrementally using a 20-ml syringe with the intention of avoiding intraneural injection. The needle tip was repositioned under ultrasound guidance so that a circumferential spread of the solution could be produced. Either 0.5 % ropivacaine or 1.5 % mepivacaine with 1:400,000 epinephrine was chosen for the anesthetic according to the type of surgery planned: patients undergoing ACL reconstruction received the former and the others received the latter. All patients also received ultrasound-guided femoral nerve and lateral femoral cutaneous nerve blocks, and some obturator nerve block if needed for surgery. The patients were sedated with midazolam, fentanyl, or propofol by request during surgery.

Ultrasound still and video images during the sciatic nerve block were captured and reviewed later. Those in whom ultrasound images were poor or intraneural injection was observed were excluded from the study. Intraneural injection of local anesthetic was defined as apparent swelling of any part of the nerve in the cross-sectional view while local anesthetic was being injected. The sensory and motor blockade was evaluated every 5 min for 30 min and postoperatively on the evening of surgery and on the next morning (in patients given mepivacaine) or on the next two consecutive mornings (in those given ropivacaine). Sensory function was examined by pinprick (20 G needle) on the plantar aspect of the foot (tibial nerve), the dorsal aspect of the foot (superficial peroneal nerve), and the posterolateral area of the leg (sural nerve). The sensory block was considered complete when the patient did not feel a pinprick sensation. Motor block was examined in the foot and the toes and considered complete when the patient could neither plantarflex nor dorsiflex them. In addition, patients were asked to carefully record when the sensory and motor blockade completely disappeared. Data collected included block execution time for the sciatic nerve block, minimal current to elicit motor response, and the duration of blockade of the sciatic nerve (time to complete recovery of sensation on the dorsal aspect of the foot and motor recovery of foot movement).

Data were compared in two ways: regarding the motor response pattern between the response of the tibial nerve and the common peroneal nerve, and regarding the minimal current between low current (< 0.5 mA) and high current (≥0.5 mA). Statistical analysis was performed using Statview (Abacus Concepts, Berkeley, CA, USA). Continuous variables and nominal data were compared between the two groups using an unpaired Student's t test and a χ^2 test, respectively. $P < 0.05$ was considered statistically significant.

Results

Of 429 patients enrolled in the study, 278 and 151 patients received mepivacaine and ropivacaine, respectively. For patients receiving mepivacaine, 57 were excluded from the study because of insufficient documentation of data. Later, 10 patients were excluded by poor video images and another 41 were excluded for occurrence of intraneural injection (Fig. 1). For patients receiving ropivacaine, 28 were excluded for insufficient documentation of data, 4 for poor video images, followed by 20 patients excluded for occurrence of intraneural injection. Thus, data from 170 patients receiving mepivacaine and 99 patients given ropivacaine were analyzed.

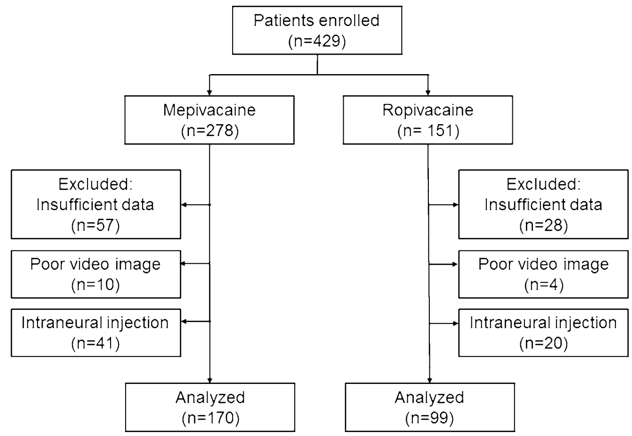

Fig. 1 Patient flow diagram

Table 1 Patients and block characteristics with mepivacaine (groups divided by response pattern)

	Tibial ($n = 103$)	Peroneal ($n = 67$)	P
Sex (male/female)	55/48	39/28	0.647
Age (years)	34 (16)	31 (16)	0.383
Height (cm)	165 (9)	167 (10)	0.576
Weight (kg)	62 (12)	65 (15)	0.218
Block execution time (min)	4.4 (2.3)	4.9 (2.6)	0.266
Minimum stimulating current (mA)	0.44 (0.13)	0.46 (0.14)	0.483
Duration (h)	8.0 (3.0)	7.6 (2.0)	0.463
Neurological complications	0	0	

Data are expressed as mean (SD) or absolute numbers

There were no differences between the two groups

In terms of patients given mepivacaine, the number of patients who showed motor response of the tibial and the common peroneal nerves was 103 and 67, respectively (Table 1). The progress of sensory and motor blockade was similar between patients with different motor response patterns (Fig. 2a). The number of patients who responded to the low minimal current and the high minimal current was 106 and 64, respectively (Table 2). The proportion of patients who developed sensory block of the tibial and sural nerve and motor block of the foot at 30 min was higher in the low minimal current group than in the other

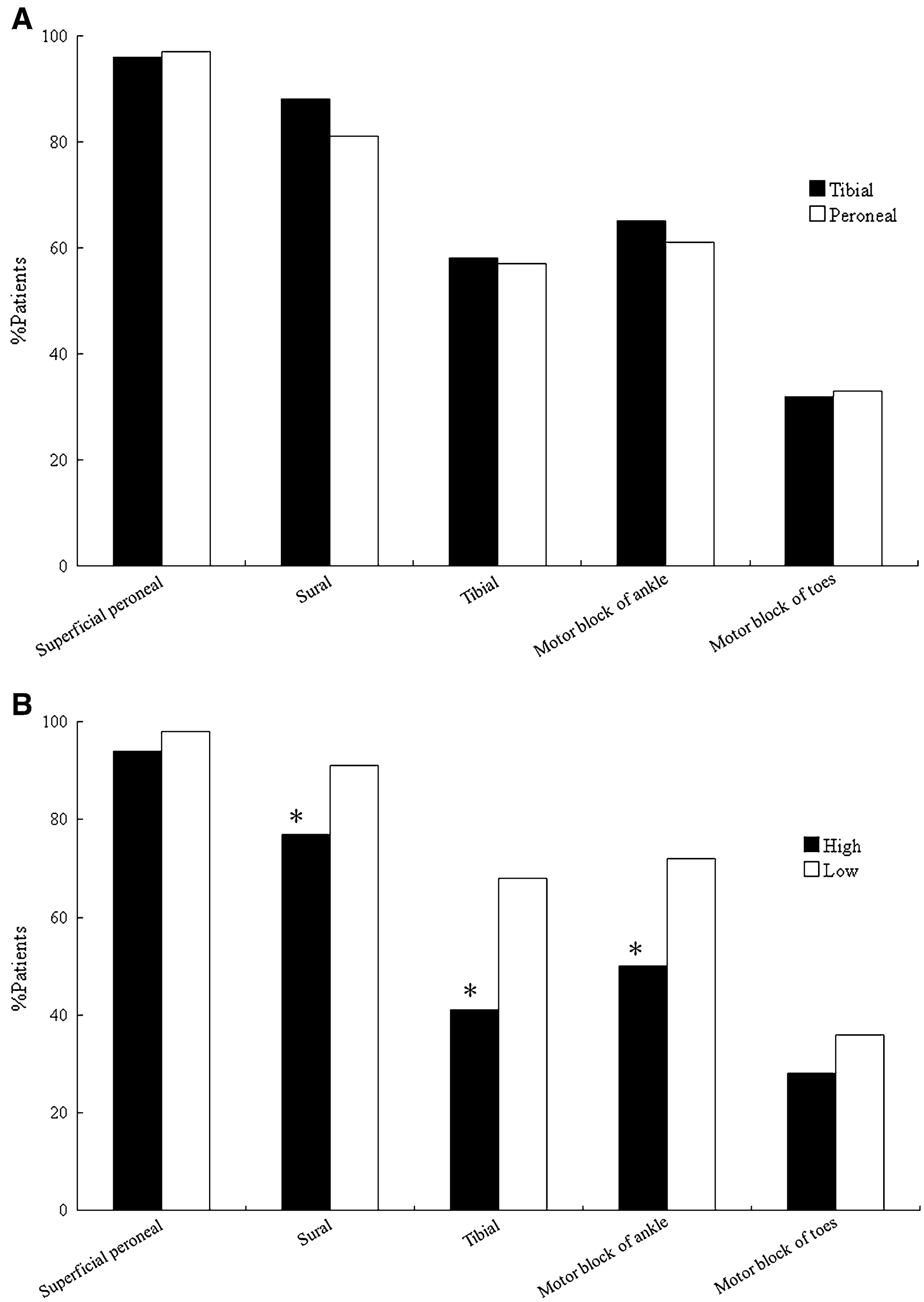

Fig. 2 Percentage of patients given mepivacaine with sensory blocks in superficial peroneal, sural, and tibial nerves, and motor blocks of ankle and toes at 30 min after the block in groups divided by response pattern (tibial nerve group, $n = 103$; common peroneal nerve group, $n = 67$) (**a**) and in groups divided by minimal current (high current group, $n = 64$; low current group, $n = 106$) (**b**). $*P < 0.05$ versus low current group

group (Fig. 2b). Block execution took more time in patients who required higher evoked current than in the others. Block duration was similar regardless of the response pattern, but longer in patients with lower minimal evoked current than in those with higher current. One patient who showed motor response of the common peroneal nerve to the high minimal current failed to develop sufficient sciatic nerve blockade for surgery and received general anesthesia.

In terms of patients given ropivacaine, the number of patients who showed motor response of the tibial and the common peroneal nerves was 57 and 42, respectively (Table 3). The progress of sensory and motor blockade was similar between patients with different motor response patterns (Fig. 3a). The number of those who responded to the low minimal current and the high minimal current was 55 and 44, respectively (Table 4). Block execution required more time in patients who required higher evoked

Table 2 Patients and block characteristics with mepivacaine (groups divided by minimal current)

	High ($n = 64$)	Low ($n = 106$)	P
Sex (male/female)	38/26	56/50	0.501
Age (years)	34 (17)	32 (15)	0.320
Height (cm)	167 (9)	166 (9)	0.338
Weight (kg)*	67 (13)	62 (13)	0.027
Block execution time (min)*	5.3 (2.4)	4.3 (2.5)	0.011
Response pattern (tibial/peroneal)	34/30	69/37	0.166
Duration (h)*	7.3 (2.1)	8.1 (2.6)	0.032
Neurological complications	0	0	

Data are expressed as mean (SD) or absolute numbers

* $P < 0.05$ between groups

Table 3 Patients and block characteristics with ropivacaine (groups divided by response pattern)

	Tibial ($n = 57$)	Peroneal ($n = 42$)	P
Sex (male/female)	33/24	22/20	0.732
Age (years)	27 (13)	27 (13)	0.800
Height (cm)	165 (10)	166 (9)	0.596
Weight (kg)	63 (12)	65 (11)	0.526
Block execution time (min)	4.0 (1.9)	4.5 (2.0)	0.245
Minimum stimulating current (mA)	0.49 (0.15)	0.47 (0.14)	0.521
Duration (h)	16.7 (4.8)	16.2 (4.0)	0.625
Neurological complications	0	0	

Data are expressed as mean (SD) or absolute numbers

There were no differences between the two groups

current. Neither progress of sensory blockade nor block duration differed between low and high current groups, but the proportion of patients who developed motor blockade in the toes was higher in the former group than in the latter (Fig. 3b).

No postoperative neurological complications were observed in any patients.

Discussion

The pattern of evoked motor response and the minimal electric current necessary to elicit motor response are the two different types of available information regarding needle tip position in relationship to neural tissues when nerve stimulation is used. In this retrospective study, we sought to assess these roles in the block by retrospectively analyzing data from which comparison was made between groups that were assembled based on the type of motor response or the minimal current. As a result, we demonstrated that the type of motor response did not affect the progress or duration of blockade after ultrasound-guided subgluteal sciatic nerve block combined with nerve stimulation using either mepivacaine or ropivacaine. In terms of the stimulation threshold, we found that the development of blockade was faster and block duration was longer when the minimal evoked current was low. The effects, however, were less apparent after ropivacaine than after mepivacaine.

To the best of our knowledge, this is the first study exploring the role of nerve stimulation used in ultrasound-guided sciatic nerve block. According to the results of previous studies [4,10–13] conducted before ultrasound technique was utilized in the block, the type of evoked motor response with nerve stimulation was a factor markedly affecting the latency and success of various types of single sciatic nerve block. For example, Benzon et al. [10] showed that elicitation of foot inversion was more reliably associated with complete sciatic nerve blockade than eversion, plantarflexion, or dorsiflexion of the foot during sciatic nerve block at the popliteal fossa. At the subgluteal level, Sukhani et al. [4] showed that evoked motor response type during nerve stimulator-assisted single-injection sciatic nerve block predicted latency and success of complete blockade. In contrast, in the present study, the type of motor response obtained did not markedly affect either the progress or duration of blockade after ultrasound-guided sciatic nerve block. Using real-time ultrasound imaging, the needle tip position was adjusted to obtain circumferential spread of anesthetic around the nerve in many cases. Thus, it is highly likely that, regardless of the initial position of the needle tip, both tibial and common peroneal components of the sciatic nerve were eventually soaked in an anesthetic solution, and that obtaining a particular motor response pattern is not important for success in the ultrasound-guided subgluteal sciatic nerve block.

In the present study, blocks with lower minimal evoked current resulted in faster onset than those with higher electrical stimulation. Sinha et al. [14] reported similar results using a different block technique. They showed that fewer patients had complete motor blockade at 15 min after ultrasound-guided interscalene block in whom motor response was obtained above 0.5 mA than those who showed motor response at or below 0.5 mA. However, the present results may be surprising in view of the intention made to obtain circumferential spread of anesthetic around the nerve as already discussed. In addition, electrical stimulation threshold is influenced by many factors. The reliability of the relationship between needle tip location to the nerve and stimulation threshold has been questioned in animal studies [15–17]. Clinical studies, using ultrasound

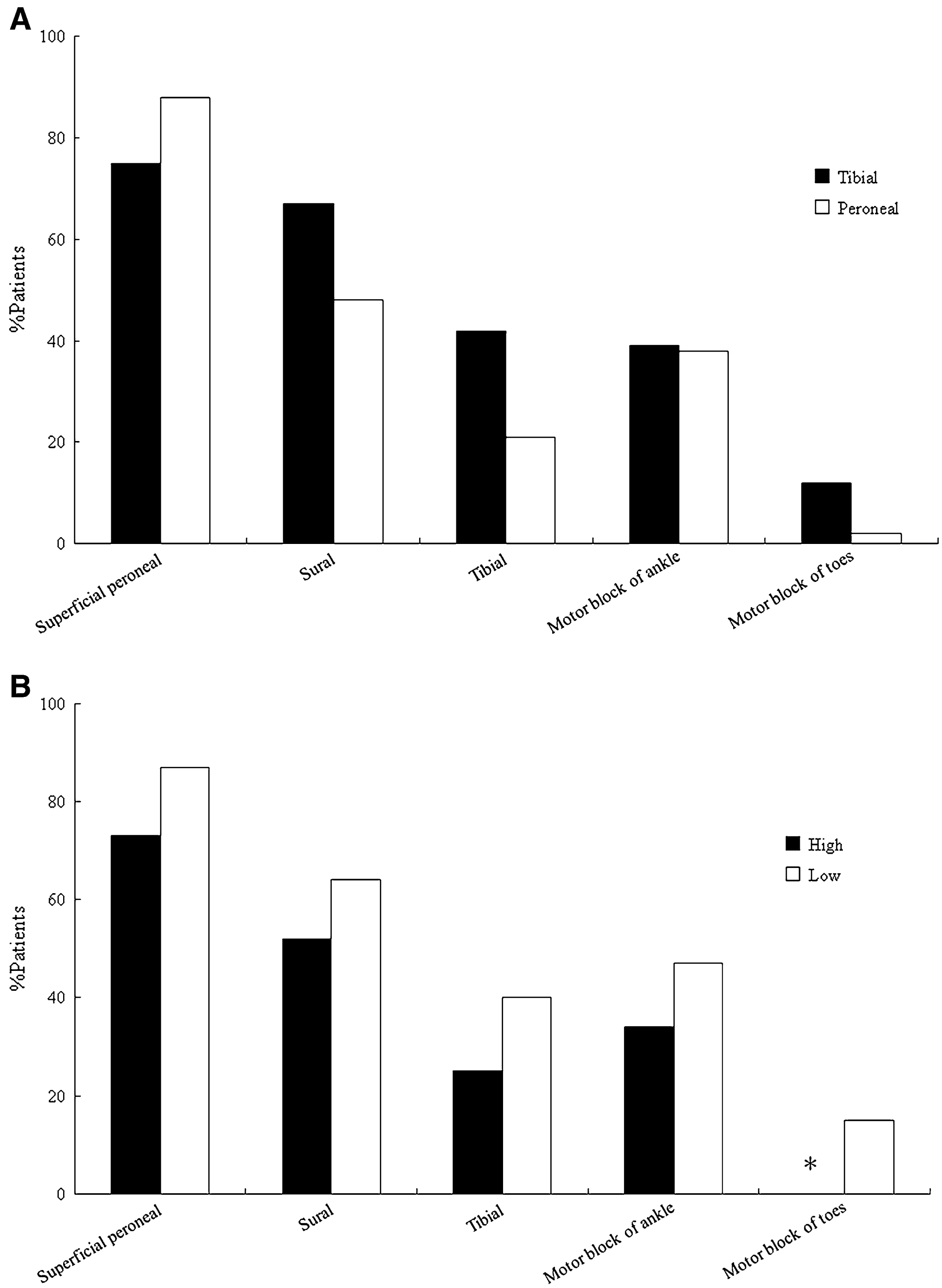

Fig. 3 Percentage of patients given ropivacaine with sensory blocks in superficial peroneal, sural, and tibial nerves, and motor blocks of ankle and toes at 30 min after the block in groups divided by response pattern (tibial nerve group, $n = 57$; common peroneal nerve group, $n = 42$) (**a**) and in groups divided by minimal current (high current group, $n = 44$; low current group, $n = 55$) (**b**). *$P < 0.05$ versus low current group

and nerve stimulation together, have also shown that electrical current threshold is not a reliable indicator of needle to nerve distance [18, 19]. Possible reasons for the observed difference are that the block performed with higher minimal current was probably more difficult to execute because it took more time and, thus, all the local anesthetic may not have been injected close to the nerve in patients in the high current group. The role of low minimal current that hastened the onset and lengthened the duration was observed less apparently with ropivacaine than with mepivacaine. The difference observed between the two anesthetics may be explained by the slower onset with the former.

In the present study, data from patients in whom intraneural injection was suspected to have occurred were excluded, because intraneural injection itself has a large impact on the progress of blockade [8]. However, the present study was retrospectively conducted, and, thus, the decision for intraneural injection may not have been accurate. Some patients who were not excluded may have received anesthetic intraneurally. Especially, patients whose evoked motor current was < 0.5 mA have a greater

Table 4 Patients and block characteristics with ropivacaine (groups divided by minimal current)

	High ($n = 44$)	Low ($n = 55$)	P
Sex (male/female)	27/17	28/27	0.402
Age (years)	25 (11)	29 (14)	0.082
Height (cm)	167 (9)	165 (9)	0.230
Weight (kg)	65 (11)	63 (12)	0.514
Block execution time (min)*	4.7 (2.4)	3.8 (1.4)	0.019
Response pattern (tibial/peroneal)	27/17	30/25	0.230
Duration (h)	15.9 (4.7)	17.0 (4.2)	0.217
Neurological complications	0	0	

Data are expressed as mean (SD) or absolute numbers

* $P < 0.05$ between groups

chance to receive intraneural injection according to the results of previous papers [20–22]. However, it is unlikely that all the differences observed between the two groups based on minimal evoked current resulted from possible difference in percentage of intraneural injection. According to the results of our previous study [9], intraneural injection could lead to faster block onset but not longer block duration.

There are at least four additional limitations, most of which are associated with the retrospective nature of the study. First, although we intended to inject local anesthetic solution to make a circumferential spread around the nerve, it was impossible to confirm what percentage of blocks really did so, partly because our study was not prospective. Whether the spread is actually circumferential may be crucial to the development of blockade. However, because the subgluteal sciatic nerve is so deeply located, local anesthetic spread would not have always been confirmed even if the study had been conducted prospectively. In contrast, ultrasound-guided circumferential injection of local anesthetic around the more superficially located popliteal sciatic nerve has been shown to improve the sensory block [23, 24]. Thus, the significant differences observed in the present study might have resulted from a difference in anesthetic spread pattern. Second, the minimal current used to divide patients into groups was set at 0.5 mA, because a motor response at or below 0.5 mA has been widely accepted as the most reliable endpoint for a successful block with nerve stimulation [14]. However, if we had chosen a different current the results might have been different. Third, needle insertion and advancement were conducted only under ultrasound guidance, and, once the response was observed at current intensity of 1.0 mA, minimal evoked current was established without adjustment of the needle. Thus, it is possible that the present results do not apply to other institutions where nerve stimulation is used differently. Finally, the number of patients used for analysis was limited, especially in those given ropivacaine. The power to reject any differences between groups was small, and thus there may have been minor (probably clinically negligible) differences in the progress of sensory and motor blockade after ropivacaine.

In conclusion, when ultrasound-guided subgluteal sciatic nerve block was conducted with nerve stimulation, motor response pattern did not markedly affect the progress of sensory or motor blockade or block duration. Lower minimal evoked current was associated with faster block onset and longer block duration after both mepivacaine and ropivacaine.

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Conflict of interest None.

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