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ORIGINAL ARTICLE

# Ultrasound-guided peripheral nerve blocks for anterior cruciate ligament reconstruction: effect of obturator nerve block during and after surgery

**Shinichi Sakura · Kaoru Hara · Junichi Ota · Saki Tadenuma**

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**Abstract**
*Purpose* Three studies were conducted to determine whether and how the obturator nerve bears relevance to intra- and postoperative pain in patients undergoing anterior cruciate ligament (ACL) reconstruction using a hamstring autograft.
*Methods* Patients undergoing arthroscopic ACL reconstruction using a hamstring autograft were enrolled in three studies. In the first study, we studied the analgesic effect of combined posterior lumbar plexus (PLP) and sciatic nerve blocks as well as combined femoral, lateral femoral cutaneous, and sciatic nerve blocks during and for 24 h after surgery. The second study was conducted to compare the analgesic effect of the combination of femoral, lateral femoral cutaneous, and sciatic nerve blocks with and without an obturator nerve block. Finally, we compared a postoperative continuous femoral nerve block and PLP block both during and for 48 h after surgery.
*Results* In the first study, patients receiving the PLP block required significantly less fentanyl intraoperatively than those given the femoral nerve block. In the second, significantly less fentanyl was required during surgery for patients with the obturator nerve block than for those without. Finally, the continuous postoperative PLP block showed higher visual analog pain scores than those with the continuous femoral nerve block during movement at 48 h.
*Conclusion* The present results suggest the involvement of the obturator nerve in ACL reconstruction using a hamstring autograft. However, although obturator nerve blockade is crucial for intraoperative analgesia, a continuous obturator nerve block is not necessary beyond 24 h postoperatively.

**Keywords** Nerve block · Obturator nerve · Knee surgery · Ultrasonography

S. Sakura (✉)
Surgical Center, University Hospital, Shimane University School of Medicine, 89-1 Enya-cho, Izumo 693-8501, Japan
e-mail: ssakura@med.shimane-u.ac.jp

K. Hara · J. Ota · S. Tadenuma
Department of Anesthesiology,
Shimane University School of Medicine, Izumo, Japan

## Introduction

Femoral and sciatic nerve blocks, in combination, often fail to provide satisfactory intra- and postoperative analgesia in patients undergoing anterior cruciate ligament (ACL) reconstruction using a hamstring autograft. This is probably because ACL reconstruction using a hamstring autograft may require blockade of the obturator nerve, which provides sensory innervation to the knee joint and the gracilis tendon. The gracilis tendon is often used as an autograft together with the semitendinosus tendon, and a femoral nerve block does not necessarily produce blockade of the obturator nerve. Thus, the blockade of entire lumbar plexus, which includes femoral, lateral cutaneous femoral and obturator nerves, or an additional obturator nerve block may increase the quality of anesthesia during surgery and postoperative analgesia.

Accordingly, a series of three studies were conducted to determine whether and how the obturator nerve bears relevance to intra- and postoperative pain in patients undergoing ACL reconstruction using a hamstring autograft. In addition, we searched for a combination of peripheral nerve blocks to provide satisfactory analgesia for this particular surgery. First, we conducted a preliminary study to

compare the efficacy of combined posterior lumbar plexus (PLP) and sciatic nerve blocks with that of combined femoral, lateral femoral cutaneous and sciatic nerve blocks. Based on the results of the first study, the second study was conducted to determine whether obturator nerve blockade contributes to the improvement of the quality of intra- and early postoperative analgesia. Finally, we compared the efficacy of two methods, i.e., a postoperative continuous femoral nerve block and PLP block, to determine whether a continuous obturator nerve block is necessary. In our three studies, we performed all peripheral nerve blocks using ultrasound guidance. This allows us to visualize in real time the nerve tissue, the spread of injected local anesthetic and the catheter insertion while performing some blocks.

## Methods

After Institutional Review Board approval and written informed consent, patients (ASA 1–2) undergoing arthroscopic ACL reconstruction using a hamstring autograft including the gracilis tendon were enrolled in three studies. Patients with a history of diabetes mellitus, neurologic disease, or infections at the site of injection were excluded.

All patients fasted for approximately 8 h before entering an operating room, where an intravenous infusion of acetated Ringer's solution was initiated at a rate of 1–3 ml/kg/h. Standard noninvasive monitors were applied, and oxygen was administered via a facemask. Fentanyl 50–100 μg with or without midazolam 1–2 mg were given intravenously for anxiolysis as necessary, while ensuring that patients remained responsive to verbal cues. Peripheral nerve blocks were performed using a handheld ultrasound device (MicroMaxx Ultrasound System, Sonosite Inc., Bothell, WA, USA) with a low-frequency, 5–2 MHz, curved array transducer (C60e) or a high-frequency, 13–6 MHz, linear array transducer (HFL38) for PLP and sciatic nerve blocks or the others, respectively. A short-bevel 100-mm, 21-gauge insulated nerve block needle (Stimuplex A, B. Braun Melsungen AG, Germany) connected to a nerve stimulator (B. Braun Melsungen AG) was used for PLP, sciatic, single femoral, and obturator nerve blocks. The needle was inserted parallel and in line with the ultrasound transducer and advanced slowly under real-time ultrasound guidance until it was in close proximity to the nerve. A nerve stimulator with a pulse duration of 0.1 ms and a stimulating frequency of 2 Hz was used to confirm the nerve. During surgery, no additional local anesthetics were administered, but patients were sedated as requested with bolus intravenous injections of midazolam 1–2 mg or a continuous intravenous infusion of propofol 2–6 mg/kg/h. If surgical anesthesia was deemed inadequate during surgery, bolus intravenous injections of fentanyl 50 μg were given at the discretion of the attending anesthesiologist. Postoperatively, patients received loxoprofen sodium 60 mg orally and/or diclofenac sodium 50 mg suppository if requested.

Sensory blockade on the operated limb was evaluated every 5 min after injection of the local anesthetic for 30 min, and again immediately and every 2 h after the completion of surgery. Sensory examination was conducted by pinprick (18G) on the anterior aspect of the thigh (femoral nerve), the medial aspect of the lower leg (saphenous nerve), the lateral aspect of the thigh (lateral femoral cutaneous nerve), the lateral aspect of the leg (lateral sural cutaneous nerve), the posterolateral area of the leg (sural nerve), and the plantar aspect of the foot (tibial nerve). The obturator nerve function was evaluated by manually assessing the strength of thigh adduction 10 min after the block. Only postoperative data were collected by an investigator who was blinded to the group assignment. Patients who did not lose pinprick sensation on the lateral aspect of the leg within 30 min after the sciatic nerve block or on the anterior aspect of the thigh within 30 min after the femoral nerve or PLP blocks were excluded from the data analysis.

### Study 1

This preliminary study recruited 30 or more consecutive patients, who were assigned to one of the following 2 groups of 15: group FN received the combination of femoral, lateral femoral cutaneous, and sciatic nerve blocks; group LP combined PLP and sciatic nerve blocks. First, patients were placed laterally with the side to be anesthetized uppermost, and they received a sciatic nerve block as described elsewhere [1]. A local anesthetic solution of 1.5% mepivacaine 20 ml with 1:400000 epinephrine was then injected incrementally. Patients in group FN were then placed in a supine position with both legs extended and they received lateral femoral cutaneous nerve and femoral nerve blocks as described elsewhere [2, 3]. Local anesthetic solutions used for the former and latter blocks were 1% mepivacaine 5 ml and 0.5% ropivacaine 15 ml, respectively. In patients in group LP, the sciatic nerve block was followed by a PLP block with 0.75% ropivacaine 30 ml while the patients were kept in the lateral position [4, 5].

Measurements included block execution time for all the blocks [time for sciatic, femoral, and lateral femoral cutaneous nerve blocks or for sciatic nerve and PLP blocks in group FN or PL, respectively, from the start of positioning a patient for the first (sciatic nerve) block to the end of the last block], time required for onset, and duration of the sensory block on the anterior aspect of the thigh. The number of patients who required fentanyl during surgery

and the usage of rescue analgesic during 24 h postoperatively were recorded. The motor function of the obturator nerve was not evaluated in this study.

### Study 2

Forty-one patients were randomly divided into two groups: group 1 received the combination of femoral, lateral femoral cutaneous and sciatic nerve blocks; group 2 additionally received an obturator nerve block. The sciatic, lateral femoral cutaneous and femoral nerve blocks were performed in that order using the same techniques and the local anesthetic solutions as study 1.

Patients in group 2 then received an obturator nerve block while the patient was placed in the supine position with the thigh slightly externally rotated. The transducer was positioned at the medial aspect of the thigh perpendicular to the skin approximately 2 cm below the inguinal ligament. The location was scanned by sliding and tilting the transducer until a clear transverse image of the adductor longus (or pectineus), adductor brevis, and adductor magnus muscles was obtained. Bolus injections of 0.5% ropivacaine 5 ml each were made between the adductor longus (or pectineus) and adductor brevis muscles and between the adductor brevis and adductor magnus muscles to block the anterior and posterior divisions of the obturator nerve, respectively [6].

Measurements included block execution time for all the blocks [time for sciatic, femoral and lateral femoral cutaneous nerve blocks with or without obturator nerve block, from the start of positioning a patient for the first (sciatic nerve) block to the end of the last block], the number of patients who required fentanyl during surgery, and the usage of rescue analgesic during 24 h postoperatively.

### Study 3

Thirty-nine patients were randomly divided into two groups: group F received a continuous femoral nerve block in addition to combined single lateral femoral cutaneous, obturator and sciatic nerve blocks; group L received a continuous PLP block and a single sciatic nerve block.

A continuous femoral nerve block was performed while the patient was placed in the supine position with both legs extended. With the transducer positioned on the inguinal crease perpendicular to the skin, a 17-gauge Tuohy needle was inserted using the out-of-plane technique and advanced slowly under real-time ultrasound guidance until it was in close proximity to the nerve without the help of nerve stimulation. A bolus injection of 0.5% ropivacaine 15 ml was made, and a catheter (Smith Medical, Kent, UK) was advanced 5–10 cm perineurally in the cephalad direction. Continuous infusion of 0.2 or 0.25% ropivacaine was started immediately after surgery at 4 ml/h with a 3 ml patient-controlled bolus available every 30 min using a portable infusion pump (Daiken, Osaka, Japan), and this lasted for at least 48 h. The concentration of the solution was at the discretion of the anesthesiologist attending the patient.

In group L, a catheter was inserted following a single PLP block. Immediately after withdrawing the insulated nerve block needle, a 17-gauge Tuohy needle was inserted from the same insertion site as the insulated block needle and advanced parallel and in line with the ultrasound transducer until it reached the local anesthetic solution injected immediately before. A catheter (Smith Medical, Kent, UK) was advanced 5–10 cm in the caudad direction. Continuous infusion of 0.2 or 0.25% ropivacaine was started immediately after surgery at 6 or 4 ml/h, respectively, with a 3 ml patient-controlled bolus available every 30 min using a portable infusion pump, and this lasted for at least 48 h. The combination of concentration and rate of the solution was at the discretion of the anesthesiologist attending the patient.

Measurements included pain intensity, which was evaluated using a visual analog scale ranging from 0 cm (no pain) to 10 cm (worst imaginable pain) at rest and during movement at 24 and 48 h, the usage of patient-controlled analgesia and rescue analgesic during the first postoperative 48 h, and side effects.

### Statistical analysis

The sample size needed for study 2 was determined by a power analysis based on the ability to detect a difference of 60% in the use of intraoperative fentanyl required with beta set at 0.2 and alpha set at 0.05. Similarly, the sample size for study 3 was determined so as to detect a difference of 2.0 cm in the visual analog scale. Minimal sample sizes of 36 patients (18 in each group) and 34 patients (17 in each group) for studies 2 and 3, respectively, met these criteria. Data are expressed as mean (range), mean (SD), median (range), or absolute numbers. The Mann–Whitney rank-sum test, Student's *t* test and the chi-square test were used

**Table 1** Patient characteristics in study 1

| | Femoral nerve group ($n = 15$) | Lumbar plexus group ($n = 15$) |
|---|---|---|
| Sex (M/F) | 7/8 | 9/6 |
| Age (years) | 26 (15–68) | 33 (16–52) |
| Height (cm) | 164 (148–178) | 163 (155–174) |
| Weight (kg) | 62 (48–72) | 63 (50–90) |

Values are expressed as the mean (range) or absolute numbers
There were no differences between the two groups

**Table 2** Block characteristics and analgesic requirements in study 1

| | Femoral nerve group ($n = 15$) | Lumbar plexus group ($n = 15$) | $P$ |
|---|---|---|---|
| Onset time (min) | 8.0 (5.9) | 15.7 (9.0) | 0.015 |
| Duration (h) | 14.4 (5.3) | 14.2 (5.3) | 0.89 |
| Execution time (min) | 24.6 (4.1) | 26.7 (7.1) | 0.35 |
| Patients requiring intraoperative fentanyl ($n$) | 15 | 8 | 0.003 |
| Analgesic requirements during 24 h after surgery ($n$) | 2 (1–5) | 3 (1–7) | 0.088 |

Values are expressed as the mean (SD), median (range), or absolute numbers

**Table 3** Patient characteristics in study 2

| | Group 1 ($n = 20$) | Group 2 ($n = 21$) |
|---|---|---|
| Sex (M/F) | 10/10 | 13/8 |
| Age (years) | 26 (15–68) | 30 (16–48) |
| Height (cm) | 164 (144–183) | 166 (148–183) |
| Weight (kg) | 65 (45–96) | 64 (50–82) |

Values are expressed as the mean (range) or absolute numbers

Group 1, patients without obturator nerve block; group 2, patients with obturator nerve block

There were no differences between the two groups

for statistical analysis. $P < 0.05$ was considered significant.

## Results

### Study 1

During the course of the study, 34 patients were recruited. Four patients who received the PLP block but did not develop sufficient anesthesia in the anteromedial aspect of the thigh were excluded. Both groups were similar in sex, age, weight, and height (Table 1). All of the patients developed anesthesia in all the area tested, except for one in group FN in whom the lateral aspect of the thigh was not anesthetized. The onset of sensory blockade was faster after the femoral nerve block than the PLP block (Table 2). However, the quality of surgical anesthesia was significantly better in group LP than in group FN. Significantly more patients required intraoperative fentanyl in group FN than in group LP. The sensory blockade lasted for a similar duration for the femoral nerve block and PLP block, and there was no difference in the usage of rescue analgesic postoperatively between the groups.

### Study 2

Of the 41 patients enrolled in the study, 21 and 20 patients received the combination of peripheral nerve blocks with and without obturator nerve block, respectively. Both groups were similar in sex, age, weight, and height (Table 3). The time required to perform all of the blocks in group 2 was longer than that in group 1 (Table 4). One in each group did not develop anesthesia on the plantar aspect of the foot within 30 min after the blocks. Manual evaluation of the obturator nerve motor function revealed that the nerve was at least partially blocked in all of the patients in group 2. All of the patients in group 1 required fentanyl during surgery, whereas six patients (28.5%) in group 2 did, and the dose of fentanyl administered intraoperatively was significantly larger in group 1 than in group 2. There was no difference in the usage of rescue analgesic postoperatively between the groups.

### Study 3

Of the 39 patients enrolled in the study, 19 and 20 patients received the combination of peripheral nerve blocks with femoral nerve and PLP blocks, respectively. Both groups were similar in sex, age, weight, height, operation time, and number of patients who required fentanyl during surgery (Table 5). Manual evaluation of the obturator nerve motor function revealed that the nerve was at least partially blocked in all of the patients. While 16 patients in group F received 0.25% ropivacaine at a rate of 4 ml/h, 18 patients in group L were given 0.2% ropivacaine at a rate of 6 ml/h (Table 6). The total dosage of ropivacaine given was significantly larger in group L than in group F. Both continuous blocks produced similar postoperative pain relief, except that patients in group F showed lower visual analog pain scores than those in group L during movement at 48 h (Fig. 1). The two groups did not differ in the number of bolus injections (Fig. 2) or rescue analgesic used postoperatively. Similar side effects were observed between the groups (Table 7).

## Discussion

ACL reconstruction is the surgical tissue graft replacement of ACL to restore its function after injury. The hamstring

**Table 4** Execution time and analgesic requirements in study 2

| | Group 1 ($n = 20$) | Group 2 ($n = 21$) | $P$ |
|---|---|---|---|
| Execution time (min) | 25.5 (4.8) | 30.3 (4.7) | 0.004 |
| Sensory block ($n$) | 19 | 20 | 0.9 |
| Intraoperative fentanyl | | | |
| $n$ | 20 | 6 | <0.0001 |
| μg | 130 (55) | 25 (45) | <0.0001 |
| Analgesic requirements during 24 h after operation ($n$) | 2 (1–5) | 1 (0–3) | 0.34 |

Values are expressed as the mean (SD), median (range), or number of patients

Group 1, patients without obturator nerve block; group 2, patients with obturator nerve block

Sensory block = patients who lost pinprick sensation in all of the area tested

**Table 5** Patient characteristics in study 3

| | Femoral nerve group ($n = 19$) | Lumbar plexus group ($n = 20$) |
|---|---|---|
| Sex (M/F)* | 15/4 | 8/12 |
| Age (years) | 26 (15–52) | 30 (14–49) |
| Height (cm) | 162 (152–176) | 166 (152–182) |
| Weight (kg) | 61 (47–98) | 62 (54–90) |
| Operation time (min) | 150 (29) | 139 (29) |
| Fentanyl during surgery ($n$) | 3 | 4 |

Values are expressed as the mean (SD), mean (range) or number of patients

* $P < 0.05$ between the two groups

**Table 6** Block characteristics and analgesic requirements in study 3

| | Femoral nerve group ($n = 19$) | Lumbar plexus group ($n = 20$) | $P$ |
|---|---|---|---|
| Catheter depth (cm) | 16 (3) | 15 (2) | 0.29 |
| Infusion duration (h) | 47 (8) | 47 (11) | 0.91 |
| NSAIDs ($n$) | | | |
| 0–24 h | 2 (0–4) | 1 (0–3) | 0.40 |
| 24–48 h | 1 (0–3) | 1 (0–3) | 0.21 |

Values are expressed as the mean (SD), median (range) or number of patients

*LA* Local anesthetic

tendon or the patellar tendon is usually harvested from the injured knee to be used as an autograft. Hamstring autografts are often made with the semitendinosus tendon accompanied by the gracilis tendon. The semitendinosus tendon is innervated by the tibial nerve, while the gracilis tendon is innervated by the obturator nerve. Thus, the combination of femoral and sciatic nerve blocks does not theoretically provide satisfactory analgesia. To the best of our knowledge, this is the first study to assess the involvement of the obturator nerve in intra- and postoperative pain with ACL reconstruction.

We performed three studies. In the first study, we found the analgesic effects of combined PLP and sciatic nerve blocks to be superior to combined femoral, lateral femoral cutaneous, and sciatic nerve blocks in terms of surgical anesthesia for ACL reconstruction using a hamstring autograft. Lumbar plexus includes femoral, lateral cutaneous femoral, and obturator nerves, and thus it appeared that the present results prove the involvement of the obturator nerve in pain with this surgery. However, because the function of the obturator nerve was not evaluated in this preliminary study, patients given the PLP block may not necessarily have had the obturator nerve blocked, and thus the results were not conclusive as to whether the difference resulted from obturator nerve blockade.

Accordingly, the second study was performed to confirm the involvement of the obturator nerve during ACL reconstruction by simply comparing two groups with and without an obturator nerve block. The results indicate that the addition of an ultrasound-guided obturator nerve block improves the quality of anesthesia with femoral, lateral femoral cutaneous and sciatic nerve blocks for this particular operation. However, the present study failed to show whether the addition of an obturator nerve block improves postoperative analgesia. The two groups did not differ in the use of rescue analgesic for 24 h postoperatively, but this may have been due to a larger dosage of fentanyl given during surgery in patients without the obturator nerve block.

To observe the involvement of the obturator nerve in postoperative pain and to search for a continuous peripheral nerve block technique to provide satisfactory postoperative analgesia, the third study was conducted. In this study, continuous infusion was made through a perineural catheter placed in the femoral nerve or PLP, and patients given the continuous femoral and PLP blocks were expected to have blockade in the femoral nerve and the femoral and obturator nerves, respectively, after the effect of these single blocks disappeared. The results showed no difference between groups in the intraoperative analgesia

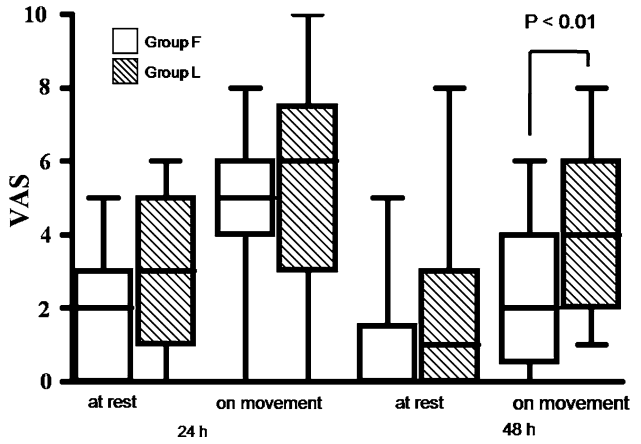


**Fig. 1** The visual analog scale values at rest and during movement 24 and 48 h after surgery in groups F and L. Group F received a continuous femoral nerve block with combined lateral femoral cutaneous, obturator and sciatic nerve blocks; group L received continuous PLP and sciatic nerve blocks. The *box* represents the 25th–75th percentiles, and the median is represented by the *solid line*. *Error bars* above and below the box mark the minimum and maximum

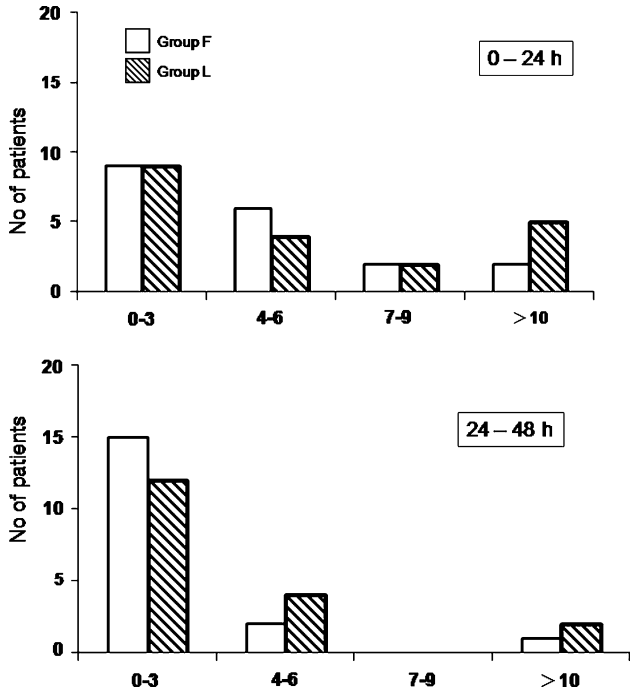


**Fig. 2** The number of 3 ml patient-controlled bolus injections of 0.2 or 0.25% ropivacaine during the first and second 24 h postoperatively in groups F and L. Group F received a continuous femoral nerve block with combined lateral femoral cutaneous, obturator, and sciatic nerve blocks; group L received continuous PLP and sciatic nerve blocks

and postoperative analgesia for the first 24 h. Considering the duration of the single femoral nerve and PLP blocks observed in the first study, it is likely that the effect of single obturator nerve blockade also lasted about 15 h after surgery. Thus, the results of the first 24 h may not have reflected any difference between the two continuous peripheral nerve block techniques.

In the third study, we found that the continuous femoral block produced satisfactory pain relief after 24 h and even slightly better analgesia than the continuous PLP block during movement at 48 h after surgery. However, careful consideration should be given to the proper interpretation of the latter results that compare the two because of some limitations to the study. First, the volume and dose of local anesthetic required to obtain satisfactory analgesia differed between the two continuous techniques; PLP needs more than femoral. Therefore, we administered larger doses (volumes) of local anesthetic for the continuous PLP block than for the femoral nerve block in the present study. However, continuous infusion of 6 ml/h of a local anesthetic solution with a 3 ml bolus might still have been rather small for a PLP block when compared with other studies [7, 8], and it may well be that at least some of our patients given the continuous PLP block did not have the obturator nerve blocked beyond 24 h after surgery. Kaloul et al. [8] administered 0.2% ropivacaine at 12 ml/h for a continuous PLP block and found that about a quarter of the patients showed evidence of motor blockade in the obturator nerve. Interestingly, they also observed that a continuous femoral nerve block using the same infusion rate produced motor blockade in the obturator nerve in about 15% of the patients. It is possible that increasing the infusion rate and/or intermittent bolus injections of larger volume improve the quality of postoperative analgesia in patients with a continuous PLP block [9, 10]. However, this would have required a larger infusion pump or more frequent changing of pumps. Second, the sensory and motor functions of the obturator nerve were not evaluated postoperatively. Thus, it is not certain that there were more patients whose obturator nerve was blocked in group L than in group F. However, the sensory assessment is meaningless because its sensory innervation to the skin is quite variable, and the surgery and the cast prevented the knee from moving properly. Finally, the concentration and rate of infusion was not standardized in the present study; there were two combinations of concentration and rate to choose from in each group. Therefore, it is possible that the choice affected the results.

The obturator nerve may play an important role in pain during and after other knee surgery as well, since the nerve provides sensory innervation to the medial part of the knee joint as well as the gracilis tendon. McNamee et al. [11] showed that the addition of an obturator nerve block to femoral and sciatic blockade improved postoperative analgesia following total knee replacement. They showed a significant increase in the time until the first request for analgesia in patients receiving the obturator nerve block.

**Table 7** Complications in study 3

| | Femoral nerve group ($n = 19$) | Lumbar plexus group ($n = 20$) | $P$ |
|---|---|---|---|
| Anesthetic leakage | 6 | 5 | 0.91 |
| Catheter dislodgement | 2 | 1 | 0.95 |
| Bleeding at insertion site | 0 | 3 | 0.24 |
| Pain at insertion site | 0 | 1 | >0.9999 |
| PONV | 5 | 5 | >0.9999 |
| Hypotension | 1 | 0 | 0.96 |

Values are expressed as absolute numbers

Macalou et al. [12] also observed significantly lower visual analog pain scores after the combination of single femoral and obturator nerve blocks than after femoral nerve block alone for the first six postoperative hours in patients undergoing total knee replacement.

In our three studies, all of the peripheral nerve blocks were performed under ultrasound guidance. Ultrasound helps to visually locate the target nerve and helps us to easily perform some peripheral nerve blocks [13–16]. In our studies, the femoral, obturator and sciatic nerves were visible in most of the patients, and blocking these nerves was almost 100% successful. In contrast, a PLP block should still be considered an advanced technique, even with ultrasound [17]. In our first study, the PLP block failed in 4 of 19 patients, while the other blocks did not. Our third study was conducted about one year after the first study, so we had more experience with the technique. Although the success rate of PLP blocks was apparently improved in the third study, we still encountered poor visualization of the lumbar plexus, as we had trouble locating it without nerve stimulation.

In conclusion, the present results suggest the involvement of the obturator nerve in ACL reconstruction using a hamstring autograft. However, although obturator nerve blockade is crucial for intraoperative analgesia, a continuous obturator nerve block is not necessary beyond 24 h postoperatively. Thus, it is recommended that a continuous femoral block should be the technique of choice after this surgery.

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