The effect of 3-in-1 femoral nerve block with ropivacaine 0.375 % on postoperative morphine consumption in elderly patients after total knee replacement surgery

Mehmet Özen*, Nurten İnan*, Filiz Tümer*, Ahmet Uyar*, Bülent Baltacı*

ÖZET

Total diz protezi uygulanan yaşlı hastalarda %0.375 ropivakain ile yapılan üçü bir arada femoral sinir bloğunun, postoperatif morfin tüketimine etkisi

Ortopedik cerrahi operasyonları içinde en ağrılı prosedürlerden biri total diz protezi (TDP) operasyonlarıdır. Calışmamızda, TDP operasyonlarında , 40 ml %0.375 ropivakain ile uygulanan preoperatif 3'e1 femoral sinir bloğunun (FSB), postoperatif hasta kontrollü analjezi (HKA) yöntemi ile uygulanan morfin tüketimine etkisini araştırmak amaçlanmıştır. Aynı zamanda, bloğun yan etki insidansına etkisi de incelenmiştir. Çalışmaya 34 hasta dahil edilerek , grup R'ye (n=17), 40 ml, %0.375 ropivakain ile preoperatif dönemde 3'e1 FSB uygulanmıştır. Grup S'ye (n=17), blok uygulanmayıp, operasyon bitiminden 30 dk önce 2 mg morfin yükleme dozu olarak verilmiştir. Her iki gruba genel anestezi verilmiş ve postoperatif dönemde HKA uygulanmıştır. Hastaların VAS skalaları, total morfin tüketimi ve yan etkileri not edilmiştir. Her gruptan 2 hasta çalışma dışı bırakılmıştır. Çalışmamızda postoperatif 0,1,2,3,4,6,8 saatlerde takip edilen VAS skorları blok uygulanan grupta anlamlı olarak düşük bulunmuştur ($p<0.05$). Grup R uyanma odasında ve postoperatif 8 saat boyunca hiç ağrı tanımlamazken, grup S VAS≤3 düzeyine postoperatif 1. saatte ulaşabilmiştir. Morfin ihtiyacı, grup R de 12., 18., 24., 48. postoperatif saatlerde anlamlı olarak düşük bulunmuştur ($p<0.001$). Yan etki insidansı da grup R de daha düşük olarak tespit edilmiştir. TDP ameliyatı geçirecek olan yaşlı hastalarda, 40 ml %0.375 ropivakain ile uygulanan preoperatif 3'e1 FSB daha etkili analjezi, daha düşük morfin tüketimi ve daha az yan etkiye sebep olmuştur.

Anahtar kelimeler: Postoperatif analjezi, üçü bir arada femoral sinir bloğu, ropivakain

SUMMARY

Total knee replacement (TKR) is one of the most painful orthopedic surgical procedures. This study was aimed to investigate the effect of a single-shot preoperative 3-in-1 femoral nerve block on postoperative pain by using 0.375% ropivacaine, and on the consumption of morphine by using PCA following the TKR surgery. Side effects were also evaluated in this setting. 34 patients were included in this study. Group R (n=17) received a 3-in-1 femoral nerve block (FNB) with 40 mll of ropivacaine 0.375%. Group S (n=17) received only a 2 mg loading dose of morphine 30 minutes before the end of surgery, and no block was performed. Both groups received general anesthesia and postoperatively had a PCA pump programmed to deliver morphine. VAS scores at rest, morphine consumption and adverse effects were recorded. Two patients were excluded from each group. Pain scores at 0, 1, 2, 3, 4, 6, 8 postoperative hours were significantly lower in group R in resting position ($p<0.05$). Group R experienced no pain at the recovery room and this state lasted 8 hours after the surgery while group S reached the acceptable score (VAS ≤ 3) one hour after leaving the recovery room. The morphine requirement was significantly lower in Group R at 12, 18, 24, 48 hr after TKR ($p<0.001$). Side effects were also lower in this group. Preoperative single-shot 3-in-1 FNB with 40 cc of ropivacaine 0.375% provides better VAS scores, less morphine consumption and fewer side effects in elderly patients when compared to the group with no block.

Key words: Postoperative analgesia, 3-in-1 femoral nerve block, ropivacaine

(*) SB Ankara Eğitim ve Araştırma Hastanesi, Anesteziyoloji ve Reanimasyon Kliniği

Başvuru adresi:
Uzm. Dr. Nurten İnan, Kenedy Cad., 28/43, Kavaklıdere, 06660, Ankara
Tel: (0 312) 595 31 76 Faks: (0 312) 466 36 26 e-posta: nurteninan@yahoo.com

(*) Ministry Of Health Ankara Research and Training Hospital, Anesthesiology Department

Correspondence to:
Nurten İnan, MD., Kenedy Cad., 28/43, Kavaklıdere, 06660, Ankara, TURKEY
Tel: (+90 312) 595 31 76 Fax: (+90 312) 466 36 26 e-mail: nurteninan@yahoo.com

Introduction

Total knee replacement (TKR) is one of the most painful orthopedic surgical procedures. Patients undergoing TKR are commonly old and have limited cardiac and pulmonary reserves. The increased sensitivity to drugs in the elderly also necessitates choosing a method and agent with minimal side effects for postoperative analgesia (Priebe 2000). Postoperative pain relief can be achieved by a number of techniques such as intravenous (IV) patient-controlled analgesia (PCA), epidural analgesia and lumbar and sciatic nerve blocks. It has been demonstrated that regional techniques provide better pain relief and allow more complete and faster postoperative knee rehabilitation than IV PCA with morphine (Singelyn et al 2000, Singelyn et al 1998). Compared with epidural anesthesia, "3-in-1" block is associated with fewer side effects and is an effective regional component of a multimodal analgesic strategy after TKR surgery (Barrington et al 2005). The relative potency of local anesthetic solutions might further influence the doses and volumes required to obtain the same clinical effect. Ropivacaine is the most suitable local anesthetic for the elderly as it has a low incidence of cardiac side effects. Although some studies report that increased local anesthetic volume (Casati et al 2001) or various concentrations (Ng 2001), do not influence the quality of the block and the analgesia duration when 3-in-1 FNB is used for knee surgery, there are also studies reporting the opposite (Wang et al 2002).

The aim of this randomized, blinded, prospective study was to investigate the efficiency of a single-shot, preoperative 3-in-1 femoral nerve block using 40 ml of 0.375 % ropivacaine in relieving postoperative pain following TKR surgery. In this setting, we also aimed to test the duration of analgesia, rescue morphine consumption and side effects in these patients compared with the control group during the 48-hour postoperative period.

Material and Method

After approval of the ethics committee and obtaining written informed consent from the patients, this prospective, randomized, two parallel group study was performed on 34 patients aged 50-75 years, ASA status I-III, scheduled to undergo one-sided TKR surgery.

During the preoperative visit, all patients were instructed on the use of the PCA apparatus and were also given detailed information about the Visual Analogue Scale (VAS). Exclusion criteria were age <50 or >75 years, weight <50 or >100 kg, undergoing tumor surgery or immunosuppressive therapy, preexisting peripheral neuropathy or neurological deficits, allergy to local anesthetics, and inability to understand the pain scale or patient-controlled analgesia (PCA) device usage. All the patients were premedicated with 0.15 mg/kg diazepam and 0.015 mg/kg atropine intramuscularly half an hour before the operation. Standard monitoring was used during the study. The patients were randomly divided into two groups. Computer-assisted randomized treatment assignments were contained in sequentially ordered, sealed envelopes, which were opened just before the 3-in-1 block was used. Group R, n=17; The 3-in-1 femoral block was performed by injecting 40 ml of 0.375 % ropivacaine before the general anesthesia and 30 minutes before the operation. Group S, n=17, received no peripheral nerve blockade before general anesthesia. In the present study sham block was not performed as it was invasive procedure and was not approved by ethics committee. Thirty minutes before the end of the operation, 2 mg morphine was given intravenously (IV) to all patients as a loading dose and an IV PCA device was connected in the postoperative period. Group R received a 3-in-1 femoral nerve block 30 minutes before operation. The femoral artery was palpated and the inguinal ligament and sulcus identified. After skin disinfection, 3 ml of 2 % prilocaine was used for local anesthesia. A 50 mm/22 gauge peripheral nerve stimulator needle (Stimuplex-Canule A.B. Braun, Melsungen AG, Germany) was then inserted at a point 1 cm lateral to the femoral artery and 1 cm inferior to the inguinal ligament. The femoral nerve was identified by the quadriceps motor reaction and patellar movement detected with 0.4-0.5 mA impulses. After ensuring that no blood was coming through with negative pressure aspiration, 40 ml of ropivacaine 0.375 % was given to the femoral nerve sheath. Distal pressure was applied in order to increase the diffusion of the local anesthetic. The existence of sensorial block in the obturator and lateral femoral cutaneous nerve dermatomes was tested by the pin-prick test. All blocks were performed by two anesthesiologists with substantial expertise in regional anesthesia, and were assessed by an independent, blinded observer. Patients with more than 80 %

sensorial block in one dermatome (for the femoral nerve, lateral cutaneous femoral nerve and obturator nerve) were accepted as having a successful block.

Both groups were given general anesthesia. After induction with 5-7 mg/kg thiopental sodium, 0.1 mg/kg vecuronium and 1 microgram/kg fentanyl, anesthesia was maintained by the inhalation of nitrous oxide/oxygen (50%) and sevoflurane. Vecuronium and fentanyl were also used during the surgery as needed. The consumption of opioids and the patients' hemodynamic findings were recorded during the surgery.

Analgesic treatment was started in the postanesthesia care unit. Treatment was given for 48 hours. Intravenous PCA was applied with a pump (Abbott Pain Manager; Abbott Laboratories, North Chicago, IL) postoperatively. The PCA regimen for both groups was 1 mg bolus with a 15-minute lockout period. The morphine concentration was 0.3 mg/ml. Patients whose analgesia was inadequate received 1 mg boluses of morphine, every 10 minutes, until VAS was achieved 3 or less in the postanethesia care unit. Demographic data such as gender, age, ASA status, weight and height and the duration of surgery were recorded. The intensity of the pain of the patients was evaluated in the resting position only at 0, 1, 2, 3, 4, 6, 8, 10, 12, 18, 24, 36, and 48 hours. For VAS the patients were asked to mark their pain on a 10 cm scale that had 0 (no pain) at the beginning and 10 (worst pain) at the end. A VAS value ≤ 3 was accepted to be an adequate level of analgesia. The amount of morphine consumed in the mentioned hours was recorded with the blood pressure, pulse, pain scale value and side effects. The patients were monitored for side effects (nausea, vomiting, itching, dryness of mouth, sweating, urinary retention, sedation, respiratory depression, hypotension, tachycardia, hematoma in the injected area and infection) that could be caused either by morphine or the nerve block. The teams administering the anesthesia and monitoring postoperative pain were blind to the study groups. Cases where the respiration rate was below 10/min were defined as having respiratory depression. Sedation was evaluated with a score of 4; 1: awake, 2: reacting to verbal stimuli, 3: reacting to the painful stimuli, 4: no reaction. A heart rate below 50 beats/minute was accepted as bradycardia and a decrease in the average arterial pressure by 30% compared to the baseline value was accepted as hypotension. Metoclopramide 10 mg iv was given for vomiting, nausea and retching, phenyramine 5 mg iv for itching, naloxan 0.1 mg iv every 2-3 minutes until a response was obtained for depression of respiration, atropine 0.5 mg iv for bradycardia, and 1000 ml of crystalloid infusion for hypotension followed by ephedrine 2.5 mg iv if there was no response.

Statistical analysis

When power analysis was performed, a sample of 15 patients in each group was sufficient for a p level <0.05 with 95% power. Non-parametric tests were used for the analysis between the two groups, owing to the number of patients and the characteristics of the distribution of the changes compared. The Wilcoxon test was used for comparison within groups and $p<0.05$ was considered significant. The "Chi Square Test" was used for inter-group comparison of nominal values and side effects whereas numeric values were compared using the "Mann- Whitney U Test". The data were expressed in terms of the mean and standard deviation and a p value less than 0.05 was considered significant.

Results

Two patients from group R had difficulty cooperating. Two patients from group S had severe postoperative hypotension that necessitated abortion of morphine administration although it was required for pain and removal of the patients from the study.

Demographic and clinical values

The demographic and clinical values of the 30 patients involved in the study are shown in Table 1. No significant difference was noticed between the groups in terms of sex, age, height, ASA, weight and the duration of surgery ($p>0.05$).

VAS values

Average VAS values for both groups are shown in Figure 1. In group R, the postoperative pain-free period continued for 8 hours. VAS rest scores were significantly lower in group R during the 0, 1, 2, 3, 4, 6, 8 postoperative hours (Figure 1) ($p<0.05$). While VAS$\leq$3, considered to be an adequate analgesia level, was reached at 0 min in group R, it was reached one hour postoperatively in group S. The highest average VAS value in the block group was one.

Table 1. Demographic and Clinical Values (Mean± SD).

	Group R n = 15	**Group S** n = 15
Sex (F/M)	11 / 4	10 / 5
Age	64.3 ± 8.6	64.8 ± 5.2
Weight (kg)	81.2± 17.1	76.9 ± 15.9
Height (cm)	162.3 ± 8.3	160.2 ± 9.3
ASA (I/II)	14 / 1	11 / 4
Duration of surgery (minutes)	102.5 ±21.3	98.5 ± 38.0

n: number of patients, F: female, M: male,
Group R: Preemptive 3-in-1 FNB group + IV PCA with morphine ; Group S: IV PCA with morphine.
ASA: American Society of Anesthesiologists physical status

Morphine consumption

There was a statistically significant difference in terms of morphine consumption between two groups at the 12th, 18th, 24th and 48th hours (p<0.001) with lower values in group R. The difference in total morphine consumption between the two groups was statistically significant (p<0.001) (Table 2).

Side effects

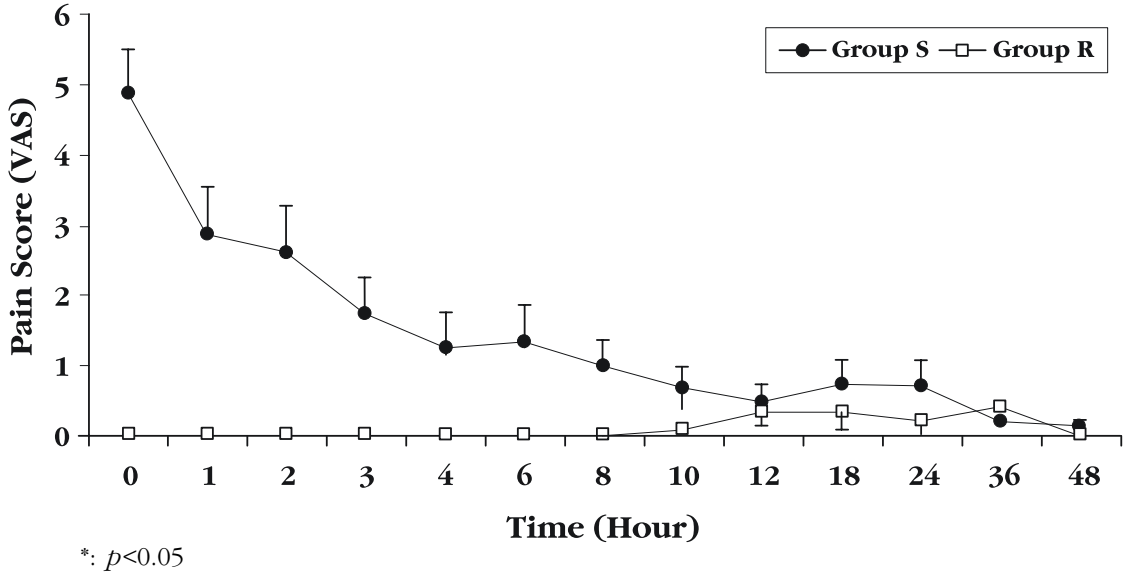
There were no complications during the application of the 3-in-1 femoral nerve block. In group S, 8 patients had nausea, 6 had vomiting and 3 had hypotension. The hypotensive patients recovered with IV fluid treatment. In group R, only four patients had nausea and all responded to treatment.

Discussion

In this study the 3-in-1 femoral nerve block was used preoperatively in elderly patients undergoing total knee replacement with the aim of providing postoperative analgesia. We found that the single-shot 40 ml 0.375 % ropivacaine used for the block led to a significant decrease in postoperative morphine consumption and was associated with fewer side effects.

Preemptive nerve block has a part in postoperative pain therapy and according to some recent studies it can prevent the central hypersensitivity that occurs as a result of surgical trauma. It has also been suggested that preemptive analgesia may prevent or decrease the pain memory that develops in the nervous system following painful stimuli (Wall 1988). Besides the mentioned advan-

Figure 1: Mean Pain Score ± SEM (VAS: 0 to 10) values during postoperative 48 hours in both groups.



*: p<0.05

Table 2: Morphine consumption of the groups: (Mean ± SD).

Cumulative morphine consumption (mg)	**Grup R** n = 15	**Grup S** n = 15
12 th hour	4.7 ± 3.7*	25.5 ± 9.9
18 th hour	7.7 ± 5.9*	32.4 ± 13.3
24 th hour	10.8 ± 6.7*	40.3± 11.8
48 th hour	21.8 ± 7.6*	67.0 ± 13.6

*:$p<0.001$

Grup R: Preoperative 3-in-1 FNB group, Group S: IV PCA group

tages, symptoms such as paresthesia or pain during the block in the awake patient decrease the risk of intraneural injection. Dermatomal innervations and motor blocks of the related nerves (especially the obturator nerve) can also be better evaluated in awake patients .

The sensorial innervations of the knee are provided by the lumbar plexus (LP) and the sacral plexus (SP) (Williams et al. 1995). Whether lumbar or sacral components are more effective in the sensorial innervations of the knee is unknown. The results of our study, as reported by other studies, indicate that lumbar plexus blockage is adequate by itself to provide analgesia in TKR surgery.

Another question is the degree of analgesic efficiency of the obturator nerve blockade for TKR surgery. Mc Namee et al (2002) asserted that it was beneficial while Kaloul et al (2004) stated that obturator nerve blockade did not make any difference. Macalou and Truech (2004) have indicated that obturator nerve blockade is inadequate as some patients continue to have pain following total knee replacement although sciatic nerve block is added to 3-in-1 femoral nerve block. They have added isolated obturator nerve block to a 3-in-1 femoral nerve block and compared this with a 3-in-1 femoral nerve block. The group with the added obturator nerve block had lower morphine consumption values and VAS scores. The postoperative monitoring period was six hours and the VAS values were determined during rest. The amount of local anesthetic used was 25 ml of bupivacaine 0.5 % and lidocaine 2 % for FNB and 7 ml of the same mixture for the obturator block (Macalou and Truech 2004). In the present study 40 ml ropivacaine 0.375 % used for the 3-in-1 FNB led to a significant increase in morphine consumption and VAS values compared to the control group. This may be due to the high volume of anesthetic we used. Wang et al (2002) have obtained a similarly effective postoperative analgesia with 40 ml of 0.25 % bupivacaine. The quality of the nerve block has been linked to the volume of the local anesthetic used in many articles. Higher volumes of local anesthetics may therefore lead to better obturator nerve blockade values. The 3-in-1 femoral nerve block depends on the advancement of a high volume of local anesthetic to the proximal lumbar plexus within the nerve sheath and the simultaneous blockage of the obturator nerve and lateral femoral cutaneous nerve together with the femoral nerve at this time. Lang and Yip (1993) reported the rate of obturator nerve retention as 4 % whereas in Singelyn et al's study (1996) this percentage was as high as 40 %-55 %. Although bupivacaine was used in both studies, the quantity was 30 ml for Lang and Yip's (1993) study and 40 ml for Sigelyn et al's study (1996). The YaDeau JT et al (2005) study combined preoperative 3-in-1 FNB with spinal-epidural anesthesia and found more effective analgesia in the group with block at the 6th postoperative hour. The preoperative 3-in-1 FNB led to a significant decrease in the amount of morphine used at every interval measure for 48 hours postoperatively.

Local anesthetics can be given as a single-shot or by continuous infusion for 3-in-1 FNB. We preferred the single shot 3-in-1 FNB technique instead of a continuous block. Administering a 3-in-1 FNB is easy and has a low neurological complication rate (3/10309 cases) (Auroy et al 2002). We did not experience any technical difficulties or complications. Ropivacaine is a long-term local anesthetic and has a favorable profile when compared to bupivacaine, another long-term anesthetic. Ropivacaine causes less central nervous system and cardiovascular system side effects than intravenously injected bupivacaine. No toxic effects have been reported with up to 250 mg of ropivacaine infused at 10 mg/min and that it causes 25 % less cardiovascular toxicity compared to

equivalent bupivacaine doses (Scott et al 1989). Regional anesthesia with ropivacaine therefore provides an added advantage as it is possible to use it in large quantities. We decided on a ropivacaine dose of 150 mg, less than the toxic dose. This amount of ropivacaine provided a continuous pain-free period for 8 hours postoperatively in almost all the cases. Marhofer et al compared ropivacaine 0.5 %, 20 ml and bupivacaine 0.5 %, 20 ml, for 3-in-1 FNB: the success of the block was 84 % in the ropivacaine group and 92 % in the bupivacaine group. They reported similar onset time and quality of sensory block with both local anesthetics (Marhofer et al 2000). We did not experience an unsuccessful block in the present study with 40 ml ropivacaine at a 0,375 % concentration. The high rate of block success was due to several reasons. First of all, the block was localized correctly by using a peripheral nerve stimulator. The volume and dose of the local anesthetic was relatively high and we applied pressure distal to the injection area. We thus ensured adequate proximal spread of the local anesthetic in the femoral sheath.

While some state that sciatic nerve blockade should be used in addition to FNB for TKR surgery (Cook et al. 2003), some believe it is unnecessary (Allen et al. 1998). In this study we did not use sciatic nerve blockade as it would mask perioperative nerve damage due to the lengthened tourniquet time and a possible compartment syndrome findings (Bromage 1993). We achieved fairly successful results without SNB.

It may be necessary to continue analgesia in the postoperative period in order to obtain preemptive analgesia. PCA with IV morphine is an effective postoperative analgesia method (Spetzler et al. 1987). Multimodal analgesia to decrease side effects and provide more effective analgesia is currently preferred. Nonsteroidal anti-inflammatory drugs have been combined with central and peripheral blockers to this effect (Barrington et al. 2005). Considering that peripheral and central sensitization will continue as long as stimuli continue to come from the surgical region, continuing analgesia in the postoperative period is essential for successful preemptive analgesia. We therefore followed the preemptive analgesia with 3-in-1 FNB block with postoperative PCA. In our study we preferred IV PCA, as it is less invasive and much easier to monitor. The 48-hour consumption of morphine in the block group was approximately one-third the amount of the other group. No pain was felt for 8 hours starting from awakening. The consumption of morphine was on average 21 mg compared to 67 mg in the other group. The results of the first pain evaluation in the recovery room provided a mean VAS value of 5 for the non-block group with the value reaching 3 an hour later. The group with block had VAS values below 3 at the first evaluation with the difference statistically significant.

In conclusion, preoperative 3-in-1 FNB using 0.375 % ropivacaine together with postoperative opioid administration is an effective method for postoperative analgesia following TKR surgery and decreases the side effects, increases the quality of analgesia, is easy to use and has a low complication rate. Furthermore, 3-in-1 FNB using a 0.375 % ropivacaine and morphine combination possesses a more favorable tolerability profile than morphine and thus also represents an attractive alternative for the treatment of severe acute pain in elderly patients as well.

References

Allen HW, Liu SS, Ware PD, Nairn CS, Owens BD: Peripheral nerve blocks improve analgesia after Total knee replacement surgery. Anesth Analg 1998; 87: 93.

Auroy Y, Benhamou D, Bargues L, Ecoffey C, Falissard B, Mercier FJ, Bouaziz H, Samii K: Major complications of regional anesthesia in France: The SOS Regional Anesthesia Hotline Service. Anesthesiology 2002; 97 (5): 1274-1280.

Barrington M, Olive D, Low K, Scott DA, Brittain J, Choong P: Continuous femoral nerve blockade Or epidural analgesia after total knee replacement: A prospective randomized controlled trial. Anesth Analg 2005; 101: 1824-9

Bromage PR: Masked mischief. Reg Anesth 1993; 18: 143-4.

Casati A, Fanelli G, Magistris L, Beccaria P, Berti M, Torri G: Minimum local anesthetic volume Blocking the femoral nerve in 50% of cases : A double-blinded comparison between 0.5% ropivacaine and 0.5% bupivacaine. Anesth Analg 2001; 92: 205-8

Cook P, Stevens J, Gaudron C: Comparing the effects of femoral nerve block versus femoral and sciatic nerve block on pain and opiate consumption after total knee arthroplasty. J Arthroplasty 2003; 18(5): 583-6.

Kaloul I, Guay J, Cote C, Fallaha M: The posterior lumbar plexus (psoas compartment) block and the three in one femoral nerve block provide similar postoperative analgesia after total knee replacement. Can J Anesth 2004; 51: 1; 45-51.

Lang S A, Yip R W: The femoral 3- in-1 block revisited. J. Clin Anesth 1993; 5: 292- 6.

Macalou D, Truech S: Postoperative analgesia after total knee replacement: the effect of an obturator nerve block added to the femoral 3- in-1 nerve block. Anesth Analg 2004; 99: 251-4.

Marhofer P, Oismüller C, Faryniak B, Sitzwohl C, Mayer N, Kapral S: Three-in-one blocks with ropivacaine: Evaluation of sensory onset time and quality of sensory block. Anesth Analg 2000; 90: 125-128.

McNamee DA, Parks L, Milligan KR: Postoperative analgesia following total knee replacement: an evaluation of the addition of an obturator nerve block to combine femoral and sciatic nerve block. Acta Anaesthesiol Scand 2002; 46: 95-9.

Ng HP, Cheong KF, Lim A, Lim J, Puhaindran ME: Intraoperative single-shot 3-in-1 femoral nerve block with ropivacaine 0.25%, ropivacaine 0.5% or bupivacaine 0.25% provides comparable 48 hr analgesia after unilateral total knee replacement. Can J Anesth 2001; 48(11): 1102-1108

Priebe H J: The aged cardiovascular risk patient. Br J Anaesth 2000; 85: 763-778.

Scott DB, Lee A, Fagan D, Bowler GMR, Bloomfield P, Limdb R: Acute toxicity of ropivacaine compared with that of bupivacaine. Anesth Analg 1989; 69: 563-9.

Singelyn FJ, Goossens F, Van Roy C, Gourverneur JM: During continuous 3-in-1 block (CB), a high position of the catheter increases the success rate of the technique. Int Monitor 1996; 8: 105.

Singelyn FJ, Deyaert M, Joris D, Pendeville E, Gouverneur JM: Effects of intravenous patient-controlled analgesia with morphine, continuous epidural analgesia, and continuous three-in-one block on postoperative pain and knee rehabilitation after unilateral total knee arthroplasty. Anesth Analg 1998;87:88-92

Singelyn FJ, Gouverneur JA: Extended "three-in-one' block after total knee arthroplasty: continuous versus patient-controlled techniques. Anesth Analg 2000; 91: 176-80

Spetzler B, Anderson L: Patient-controlled analgesia in the total joint arthroplasty patient. Clin Orthop 1987; 215: 122-125.

Wall PD: The prevention of post-operative pain. Pain 1988; 33: 289-290

Wang H, Boctor B, Verner J: The effect of single-injection femoral nerve block on rehabilitation and length of hospital stay after total knee replacement. Reg Anesth Pain Med 2002;27(2):139-144

Williams PL, Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE: Nervous system In: Ferguson

MWJ (Ed): Grays' Anatomy, 38th ed. New York. Churchill Livingstone. 1995; pp 1277-1292.

YaDeau JT, Cahill JB, Zawadsky MW, Sharrock NE, Bottner F, Morelli CM, Kahn R L, Sculco T: The effects of femoral nerve blockade in conjunction with epidural analgesia after total knee arthroplasty. Anesth Analg 2005;101:891-5