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Influence of a Tourniquet on Opioid Consumption After Local Infiltration Analgesia for Total Knee Arthroplasty

Sietske M.K. Bakker[1], Nienke M. Kosse[2], Sakib Crnic[3], Gert-Jan Scheffer[4], Rudolf Stienstra[1]

[1]Department of Anaesthesiology and Pain Medicine, Sint Maartenskliniek Nijmegen, The Netherlands

[2]Research Department, Sint Maartenskliniek Nijmegen, The Netherlands

[3]Department of Planning, Control and Analysis, Sint Maartenskliniek Nijmegen, The Netherlands

[4]Department of Anaesthesiology, Pain and Palliative Care, Radboudumc, Nijmegen, The Netherlands

ORCID IDs of the authors: S.M.K.B. 0000-0003-4804-8348; N.M.K. 0000-0001-9532-9359; R.S. 0000-0002-0523-4530.

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Abstract

Objective: Local infiltration analgesia (LIA) with ropivacaine is increasingly used to provide postoperative analgesia after total knee arthroplasty (TKA). TKA may be performed with or without the use of a tourniquet. The absence of local blood flow when infiltrating local anaesthesia below an inflated tourniquet may affect the rate of systemic absorption, and this may have an effect on the duration and intensity of analgesia as compared with LIA without the use of a tourniquet. The aim of the present study was to investigate the influence of tourniquet use during surgery on the time to first request (TTFR) of opioids and opioid consumption.

Methods: Two historical time-based cohorts (one with and one without tourniquet during surgery) of 300 patients underwent primary TKA under spinal anaesthesia and received LIA to provide postoperative analgesia. The cohorts were compared for TTFR of opioids and opioid consumption.

Results: TTFR did not significantly differ between the tourniquet and non-tourniquet groups with a median (25^{th}-75^{th} percentile) of 240 (102-651) and 282 (100-720) min, respectively. The median (25^{th}-75^{th} percentile) oxycodone use was higher in the tourniquet group with 50 (20-90) versus 40 (10-77.5) mg (p=0.01).

Conclusion: There was no difference in the time to first opioid consumption, suggesting that the presence of an inflated tourniquet during local anaesthetic injection does not alter systemic absorption sufficiently to affect the duration of analgesia. However, the use of a tourniquet was associated with a higher opioid consumption, which is most likely caused by pain resulting from the tourniquet itself.

Keywords: Anaesthetics, analgesics, arthroplasty, knee, local, opioid, ropivacaine, tourniquets

Introduction

Total knee arthroplasty (TKA) is usually performed in the setting of an enhanced recovery protocol. TKA may be associated with severe postoperative pain that may hamper early mobilisation. Therefore, adequate pain relief is an essential part of enhanced recovery. In many centres, local infiltration analgesia (LIA) in combination with oral analgesics has been introduced as the preferred method of postoperative analgesia because it combines adequate analgesia with a minimum of side effects (1, 2). LIA protocols may vary with regard to dose and additives but are characterised by local infiltration of the tissues surrounding the knee joint with a long-acting local anaesthetic (LA), such as ropivacaine.

Total knee arthroplasty can be performed with or without the use of a tourniquet. When the LIA mixture is infiltrated in the absence of a tourniquet, systemic absorption will commence immediately. By contrast, in case of an inflated

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Corresponding Author: Sietske Bakker E-mail: r.stienstra@maartenskliniek.nl

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tourniquet, systemic absorption will be delayed until the tourniquet is deflated, and local blood flow is restored. On the other hand, after deflation of a tourniquet, there will be a period of hyperaemia with a concomitant increase in systemic absorption. It is not known if these differences in systemic absorption with or without tourniquet alter the pharmacokinetic profile of LIA sufficiently to affect the duration of analgesia.

Until recently, TKA was performed with the use of a tourniquet in our hospital, and LIA was performed for postoperative pain relief. The perceived advantages of a tourniquet are a dry surgical field and reduced intraoperative blood loss. However, the use of a tourniquet has become the subject of discussion. In two meta-analysis studies, Zhang et al. (3) and Tai et al. (4) showed that total blood loss is not affected by tourniquet use, but it does increase the risk of thromboembolic events and might even hinder early postoperative rehabilitation. Based on these results, our standard practice has recently been changed to performing TKA without the use of a tourniquet. The purpose of this cohort study was to investigate if the presence or absence of an intraoperative tourniquet affects the duration of LIA.

Methods

The study protocol was approved by the hospital's investigational review board. The medical research and ethics committee of Slotervaart Hospital and Reade, Amsterdam, The Netherlands reviewed the study on June 7, 2017 and determined, based on the Dutch Medical Research Involving Human Subjects Act, that the research activities described meet the requirements for exemption from ethical committee review (Notification of exemption U/17.083/P1733).

Patient demographics, procedure characteristics, opioid consumption and use of analgesics from 600 patients were extracted from the patient data management system. In mid-2016, our standard surgical procedure for primary TKA changed from perioperative tourniquet use to surgery without the use of a tourniquet. The tourniquet cohort (group T) comprised the last 300 patients who underwent primary TKA with perioperative tourniquet use before protocol change. The non-tourniquet cohort (group NT) included the first 300 patients who underwent primary TKA after protocol change. Patients who were not treated according to the standard surgical procedure and perioperative protocol for the time-period in which they underwent surgery were excluded from the study.

Procedure

In our hospital, TKA is performed according to a standard protocol, detailing the anaesthetic and surgical procedure, perioperative pain treatment and rehabilitation and discharge criteria. All patients receive spinal anaesthesia with a 0.5% 10 mg hyperbaric bupivacaine in the sitting position. Patients are turned into the lateral decubitus position for 20 min with the side of surgery dependent to achieve a predominantly unilateral block after bupivacaine injection. Upon request, patients receive conscious sedation with propofol (1-4 mg kg^{-1} h^{-1}) during surgery.

In group T, a pneumatic tourniquet is placed on the patient's thigh and automatically inflated to 50 mm Hg above systolic blood pressure. In group NT, no tourniquet is used. All patients receive LIA after the placement of implants and before wound closure. The posterior and anterior knee capsules are infiltrated with 0.2% 100 mL and 50 mL ropivacaine+5 µg mL^{-1} epinephrine, respectively. The subcutaneous tissue is infiltrated with 0.2% 50 mL ropivacaine without epinephrine. All patients receive an i.v. bolus of 10 mg kg^{-1} tranexamic acid with a maximum of 1000 mg. This dose is administered just before tourniquet release in group T. In group NT, tranexamic acid is administered in the anaesthetic room before the start of surgery. All patients receive a compression bandage before transfer to the recovery room after wound closure.

Standard oral multimodal analgesia includes 1000 mg paracetamol q.i.d., 90 mg etoricoxib once daily and 600 mg b.i.d. or 300 mg gabapentin if >60 years old. Pain is evaluated with a Numeric Rating Scale (NRS) ranging from 0 (no pain) to 10 (worst pain imaginable). NRS scores are recorded by a nurse at least once during each 8-hour shift on the orthopaedic ward. In addition, patients are instructed to contact the nurses when pain exceeds NRS 3, and these scores are recorded as well. In the recovery room, NRS scores are recorded, and in case of an NRS >3, pain relief is titrated with intravenous increments of 1-2 mg morphine or 1.5-3 mg piritramide until the NRS is ≤3. At the orthopaedic ward, breakthrough pain (NRS >3) is treated with 5-10 mg oxycodone ad libitum or i.m./s.c. opioids if oxycodone alone is not sufficient. Sporadically, tramadol is used when other opioids are not well tolerated. The distribution of opioids on the recovery and orthopaedic ward is standardised. Opioids are checked, signed and registered in the patient data management system by two nurses at the time of distribution. Patients are encouraged to mobilise starting on the day of surgery according to our standard TKA protocol. Patients must fulfil functional criteria before discharge (Table 1).

Outcome measurements

The primary outcome parameter was the time to first request (TTFR) of postoperative pain relief, defined as the time (in min) between ropivacaine infiltration and the first gift of any opioid. Secondary outcomes included length of hospital stay, transfusion requirements and the amount of opioids administered during hospitalisation. Total opioid consumption was converted to intravenous morphine equivalent, using conver-

sion factors of 0.67 for oral oxycodone (5), 0.7 for intravenous piritramide (6) and 0.05 for oral tramadol (5). An average NRS pain score at rest and during activity was calculated for each patient from all NRS scores recorded during hospitalisation; average pain scores per group are based on these individual scores.

Sample size calculation and statistical analysis

Our null hypothesis was that the presence or absence of a tourniquet would not result in differences in the TTFR. A difference of 180 min was selected as clinically relevant. Data gathered in our hospital for quality monitoring of primary TKA without the use of a tourniquet showed a standard deviation of 561 min in the TTFR. Based on these data, the sample size required to identify a difference in TTFR of at least 180 min with a power of 80% was 300 patients per group (two-sided, level of significance 0.05). Data analysis was performed using Stata version 13.1 (Stata Corp., College Station, TX, USA). Shapiro-Wilk test was used for normal distribution of data. Descriptive statistics of patient and operation characteristics are presented as percentage (95% confidence interval), mean±SD or median and interquartile range (IQR, 25th-75th percentile), as appropriate. Mann-Whitney U test was used to test the significant differences between the cohorts, and chi-square test was used for numerical and categorical variables, respectively. A p-value <0.05 was considered statistically significant.

Table 1. Functional discharge criteria

Active knee flexion ≥60°, passive knee extension 0°
Quadriceps muscle force ≥3 on the Medical Research Council Scale for muscle strength
Making independent transfers
Walking independently and safely with a walking aid
Climbing stairs independently and safely (if necessary for home situation)

Table 2. Group characteristics

	Group T (n=300)	Group NT (n=300)
Sex, M/F	107/193	125/175
Age (year)	65 (6.7)	65 (9.3)
No. of patients with age >60 years	212/300	221/300
No. of patients not receiving etoricoxib*	31/300	27/300
Weight (kg)	86 (17.3)	87 (17.7)
Height (cm)	171 (10)	170 (13)
BMI (kg m^{-2})	28.9 (5.4)	29.2 (5.2)
Duration of surgery, min	67 (15)	71 (13)
Tourniquet time	50 (44-60)	n/a
Time from LIA to tourniquet deflation	13 (10-16)	n/a
No. of patients requiring RBC transfusion	3	4
Total units of RBC transfused	5	7

*Due to allergy or kidney insufficiency. Data are presented as number of patients, mean (SD) and median (25th-75th percentile). BMI: body mass index; n/a: not applicable; RBC: red blood cell; M: male; F: female

Results

All patients underwent surgery between December 2015 and March 2017. In this period, 108 patients underwent TKA under general anaesthesia. These patients are not included in the cohorts. Patients in both cohorts had similar demographic and surgical characteristics (Table 2). In the tourniquet and non-tourniquet cohort, 31 and 27 patients respectively did not use a nonsteroidal anti inflammatory drug because of an allergy or kidney insufficiency. All patients received paracetamol and gabapentin. There was no statistically significant difference in the TTFR between the two groups with a median (IQR) of 240 (102-651) min for group T versus 282 (100-720) min for group NT (p=0.482).

Table 3. Opioid consumption I

	Group T (n=300)	Group NT (n=300)	p
TTFR	240 (102-651)	282 (100-720)	0.482
Total opioid consumption (mg in se)	38 (17-67)	27 (10-60)	0.014
Oxycodone consumption (mg in se)	33.5 (13.3-60.3)	26.8 (6.7-51.9)	0.012
Oxycodone consumption (mg)	50 (20-90)	40 (10-77.5)	

Data are presented as median (25th-75th percentile). Total opioid consumption is the sum of oxycodone and tramadol consumption, and i.v., i.m. and s.c. opioids administration is converted to intravenous morphine standard equivalent (se). Oxycodone consumption is presented as actual consumption (mg) and consumption converted to intravenous morphine standard equivalent (mg in se). TTFR: time to first request

Table 4. Opioid consumption II

	Group T (n=300)	Group NT (n=300)	p
Use of any opioid (%)	91.0 (87.2 to 93.7)	90.0 (86.0 to 92.9)	0.676
Oxycodone use (%)	90.0 (86.0 to 92.9)	88.3 (84.1 to 91.5)	0.511
Use of total parenteral opioids (%)	24.0 (19.5 to 29.2)	23.3 (18.9 to 28.5)	0.848
Tramadol use (%)	3.0 (1.6 to 5.7)	3.3 (1.8 to 6.1)	0.816

Data are presented as percentage (95% CI) of patients using postoperative opioids

There was no difference in blood transfusion requirements between the groups (Table 2). Total opioid consumption (median (IQR)) was significantly higher in group T (37.5 (17-67) mg) than in group NT (27 (10-60) mg) (p=0.014). This difference was caused by a higher oxycodone consumption of patients in group T. There were no differences in parenteral opioid and tramadol consumption nor were there differences in the percentage of patients using opioids. Tables 3 and 4 summarise data on opioid consumption.

There were no differences between the groups in the average NRS pain scores at rest (median (IQR) 1.9 (1.4-2.5) for group T and 1.9 (1.3-2.5) for group NT) and during activity (median (IQR) 3.1 (2.4-3.7) for group T and 2.9 (2.3-3.5) for group NT).

There was no difference between group T and group NT in the median length of hospital stay (median (IQR) 2 (2-3) and 2 (2-3) days, respectively).

Discussion

The purpose of the present study was to investigate the influence of an intraoperative tourniquet on the duration of LIA as determined by the TTFR of opioids. There was no difference in the TTFR between the two cohorts. Thus, our null hypothesis is retained. We found that the total opioid consumption was higher in patients in the tourniquet group. There was no difference in the length of hospital stay.

The rationale for the use of a pneumatic tourniquet during TKA is twofold: to limit intraoperative blood loss and to facilitate a bloodless surgical field. However, tourniquets are associated with several complications, such as deep venous thrombosis, wound infections and delayed functional recovery caused by tissue ischaemia underneath and distal to the tourniquet (3, 4). Tourniquet use is also associated with increased postoperative pain. The first report describing the influence of a tourniquet on postoperative pain after TKA was from 1995 (7). Several randomised controlled trials followed after the first study, with most of them reaching the same conclusion that the use of a tourniquet increases postoperative pain after TKA (8-12).

When using LIA, it stands to reason that the duration of analgesia will be affected by the absorption of the LA from the site of injection. Local blood flow is one of the main determinants of systemic absorption (13). Previous studies investigating lidocaine plasma levels after intravenous regional anaesthesia demonstrate that prolonging the tourniquet time after injection slows down peak systemic absorption and lowers peak concentration (14). Likewise or similarly, compared with performing LIA without a tourniquet, the absence of circulation at the site of injection when performing LIA with an inflated tourniquet will delay the initial absorption. Whether this delay alters the pharmacokinetic profile sufficiently to exert an effect on the duration of LIA is speculative; a delay in systemic absorption might result in an increased presence of LA at the site of injection, which might lengthen the duration of analgesia. However, in the absence of pharmacokinetic data, these contemplations remain hypothetical. We were unable to demonstrate an increased duration of analgesia in group T as determined by a difference in the TTFR, and under the conditions of the present study, we conclude that the presence or absence of a tourniquet does not affect the duration of LIA.

Although the average NRS scores were similar, total opioid consumption was significantly higher in group T. Since there was no difference in the TTFR, it appears that in group T, postoperative pain was more intense, requiring more opioids after the effect of LIA had worn off. The most likely explanation for this observation is pain resulting from the tourniquet itself.

Our findings are in agreement with the study by Ejaz et al. (8) in which patients underwent TKA without LIA. In their study, patients in the tourniquet group had a higher opioid consumption than those in the non-tourniquet group. Similar results were described by Abdel-Salam et al. (7) who reported an extended interval between opioid injections in the first 24 h after surgery in patients who underwent surgery without the use of a tourniquet.

Although a femoral nerve block is still considered the gold standard procedure by many (15, 16), LIA is increasingly used for postoperative analgesia after TKA. LIA was introduced in 2008 as a multimodal opioid-sparing technique for knee and hip surgery with the aim to achieve adequate analgesia without motor impairment and with reduced opioid-related side effects, resulting in rapid recovery and reduced length of hospital stay (2). Although in different studies mixtures used for LIA vary in composition and in volume, two systematic reviews and meta-analyses have concluded that there are no significant differences in postoperative pain scores at rest and opioid consumption between LIA and femoral nerve block (17, 18). Thus, with regard to postoperative pain relief, LIA appears to be an acceptable alternative for femoral nerve block.

Our study has several limitations. Although measuring postoperative pain scores is part of our perioperative protocol and NRS scores are recorded regularly, the exact timing of obtaining these scores is not standardised, and the number of pain scores recorded per patient may vary. Therefore, the average pain scores per group are less solid than a prospective analysis and should be interpreted with caution. However, since our patients are instructed to ask for pain relief and our perioperative protocol ensures that patients are treated with opioids when the NRS pain score is >3, we believe that the difference in total opioid consumption combined with similar average pain scores

reliably reflects a difference in the intensity of postoperative pain between the two groups, and that patients in group T need more opioids to establish adequate pain relief.

The second limitation of our study is that we did not evaluate the influence of a tourniquet on the possible differences in short-term functional recovery between the two groups. However, since patients must meet a defined set of functional criteria before discharge and we found no difference in the length of hospital stay, we conclude that under the conditions of this retrospective analysis, the use of a tourniquet does not interfere with short-term functional recovery.

Conclusion

We found no difference in the TTFR after LIA for TKA with or without tourniquet, suggesting that the effect of an inflated tourniquet during LA infiltration does not alter systemic absorption sufficiently to affect the duration of analgesia. The use of a tourniquet was associated with a higher total opioid consumption, which is most likely caused by pain resulting from the tourniquet itself.

Ethics Committee Approval: The accredited Ethics Committee (Slotervaart Hospital and Reade, Amsterdam, The Netherlands) reviewed this study and determined that it meets the requirements for exemption from Ethics committee review.

Informed Consent: This was a retrospective study in which patients were not prospectively randomized and all interventions were part of standard care protocols. All patients treated in our hospital sign an agreement in which they are informed that anonymized data may be used for scientific purposes, and informed about their right to refuse. None of the patients involved in this study used their right to refuse.

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Conflict of Interest: The authors have no conflicts of interest to declare.

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References

1. Kehlet H, Andersen LØ. Local infiltration analgesia in joint replacement: the evidence and recommendations for clinical practice. Acta Anaesthesiol Scand 2011; 55: 778-84.[CrossRef]
2. Kerr DR, Kohan L. Local infiltration analgesia: a technique for the control of acute postoperative pain following knee and hip surgery: a case study of 325 patients. Acta Orthop 2008; 79: 174-83. [CrossRef]
3. Zhang W, Li N, Chen S, Tan Y, Al-Aidaros M, Chen L. The effects of a tourniquet used in total knee arthroplasty: a meta-analysis. J Orthop Surg Res 2014; 9: 13. [CrossRef]
4. Tai TW, Lin CJ, Jou IM, Chang CW, Lai KA, Yang CY. Tourniquet use in total knee arthroplasty: a meta-analysis. Knee Surg Sports Traumatol Arthrosc 2011; 19: 1121-30. [CrossRef]
5. Pain Management: Opioid Dose Converter. Available from: http://www.paindata.org/calculator.php. Accessed January 5, 2018.
6. Information NC for B. Piritramide - Pubchem. Open chemistry database. Available from: https://pubchem.ncbi.nlm.nih.gov/compound/Piritramide. Accessed January 4, 2018.
7. Abdel-Salam A, Eyres KS. Effects of tourniquet during total knee arthroplasty. A prospective randomised study. J Bone Joint Surg Br 1995; 77: 250-3.
8. Ejaz A, Laursen AC, Kappel A, Laursen MB, Jakobsen T, Rasmussen S, et al. Faster recovery without the use of a tourniquet in total knee arthroplasty. Acta Orthop 2014; 85: 422-6. [CrossRef]
9. Ledin H, Aspenberg P, Good L. Tourniquet use in total knee replacement does not improve fixation, but appears to reduce final range of motion. Acta Orthop 2012; 83: 499-503. [CrossRef]
10. Vandenbussche E, Duranthon L-D, Couturier M, Pidhorz L, Augereau B. The effect of tourniquet use in total knee arthroplasty. Int Orthop 2002; 26: 306-9. [CrossRef]
11. Tai TW, Chang CW, Lai KA, Lin CJ, Yang CY. Effects of Tourniquet Use on Blood Loss and Soft-Tissue Damage in Total Knee Arthroplasty. J Bone Jt Surgery-American Vol 2012; 94: 2209-15. [CrossRef]
12. Kumar N, Yadav C, Singh S, Kumar A, Vaithlingam A, Yadav S. Evaluation of pain in bilateral total knee replacement with and without tourniquet; a prospective randomized control trial. J Clin Orthop trauma 2015; 6: 85-8. [CrossRef]
13. Mather LE, Tucker GT. Pharmacokinetics and biotransformation of local anesthetics. Int Anesthesiol Clin 1978; 16: 23-51. [CrossRef]
14. Tucker GT, Boas RA. Pharmacokinetic aspects of intravenous regional anesthesia. Anesthesiology 1971; 34: 538-49. [CrossRef]
15. Fischer HB, Simanski CJ, Sharp C, Bonnet F, Camu F, Neugebauer EA, et al. A procedure-specific systematic review and consensus recommendations for post-operative analgesia following total knee arthroplasty. Anaesthesia 2008; 63: 1105-23. [CrossRef]
16. Paul JE, Arya A, Hurlburt L, Cheng J, Thabane L, Tidy A, et al. Femoral nerve block improves analgesia outcomes after total knee arthroplasty: a meta-analysis of randomized controlled trials. Anesthesiology 2010; 113: 1144-62. [CrossRef]
17. Mei S, Jin S, Chen Z, Ding X, Zhao X, Li Q. Analgesia for total knee arthroplasty: a meta-analysis comparing local infiltration and femoral nerve block. Clinics 2015; 70: 648-53. [CrossRef]
18. Albrecht E, Guyen O, Jacot-Guillarmod A, Kirkham KR. The analgesic efficacy of local infiltration analgesia vs femoral nerve block after total knee arthreoplasty: a systematic review and meta-analysis. Br J Anaesth 2016; 116: 597-609. [CrossRef]