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The analgesic effect of a popliteal plexus blockade after total knee arthroplasty: A feasibility study

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Introduction: An obturator nerve block (ONB) and a femoral triangle block (FTB) provide effective analgesia after total knee arthroplasty (TKA) without impeding the ambulation, although the ONB produces motor blockade of the hip adductor muscles. The popliteal plexus (PP) in the popliteal fossa is formed by contribution from the tibial nerve and the posterior obturator nerve, innervating intraarticular genicular structures and the posterior capsule of the knee. We hypothesised that a popliteal plexus block (PPB) as a supplement to an FTB would reduce pain after TKA without anaesthetising motor branches from the sciatic nerve in the popliteal fossa.

Aim: To assess the analgesic effect of adding a PPB to an FTB in 10 subjects with significant pain after TKA.

Methods: All subjects underwent unilateral TKA with spinal anaesthesia and received an FTB. The cutaneous sensation and the postoperative pain were assessed. The primary outcome was the proportion of subjects with pain above numeric rating scale (NRS) 3 followed by a reduction to NRS 3 or below after conducting a PPB.

Results: Ten subjects with a median pain of NRS 5.5 (interquartile range [IQR] 4-8) after unilateral TKA received a PPB. All 10 subjects experienced a reduction in pain to NRS 3 or below (NRS 1.5 [IQR 0-3]) within a mean time of 8.5 (95% CI 6.8-10.2) minutes. Three subjects were completely pain free after the PPB. The ankle muscle strength was not affected.

Conclusions: The PPB provided effective pain relief without affecting the ankle muscle strength in all 10 subjects with significant pain after TKA and an FTB.

KEYWORDS
analgesia, femoral triangle block, popliteal plexus block, total knee arthroplasty

1 | INTRODUCTION

Regional analgesia is paramount for the success of the fast track strategy to provide effective analgesia, improving an early ambulation and recovery after total knee arthroplasty (TKA).[1-4] Fast track ambulation after TKA requires application of selective sensory nerve blockade without motor paralysis.

Combined femoral triangle and obturator nerve blockade provides effective analgesia after TKA and is superior in analgesia compared with a single femoral triangle block (FTB) and local infiltration

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analgesia, even when a systemic multimodal analgesia is applied.[5,6] The ability to ambulate is not critically impaired with these blocks, although injecting local anaesthetic between the pectineus and external obturator muscles, with the subinguinal obturator nerve block, produces a motor block of the hip adductors.[5] A blockade of the popliteal plexus (PP), formed by branches from the posterior obturator nerve and the tibial nerve in the popliteal fossa, may provide an equivalent analgesic effect after major knee surgery without causing any motor weakness.[7,8] In theory, it may even be more effective due to the inclusion of the tibial nerve contribution to the genicular innervation from the PP.

The PP entwines the popliteal artery and vein contiguous to the adductor hiatus in the popliteal fossa[7,8] and innervates the posterior capsule as well as intraarticular genicular structures.[7] It was recently confirmed in a cadaver study that injection of 10 mL of dye into the distal end of the adductor canal spreads via the adductor hiatus to the popliteal fossa and stains the PP.[8]

In this non-randomised, unblinded, feasibility study of patients with significant pain after TKA despite an FTB, we aimed to assess whether a supplemental popliteal plexus block (PPB) would reduce the pain.

We hypothesised that anaesthetising the PP by injecting 10 mL of local anaesthetic in the distal part of the adductor canal would reduce pain after TKA from pain above numeric rating scale (NRS) 3 to NRS 3 or below.

2 | MATERIALS AND METHODS

This pilot study was a non-randomised and unblinded clinical feasibility trial. All subjects underwent primary TKA under spinal anaesthesia and received an FTB postoperatively. The patients who presented with pain above NRS 3 received a supplemental PPB.

2.1 | Ethics

The study was approved by the Danish Medicines Agency (EudraCT nr. 2017-001644-35), the Central Denmark Region Committee on Biomedical Research Ethics (1-10-72-98-17), the Danish Data Protection Agency (1-16-02-186-17) and was monitored by the Good Clinical Practice (GCP) Unit at Aalborg and Aarhus University Hospitals. Written informed consent was obtained from all subjects. The study was registered at ClinicalTrials.gov (NCT03198403) and complied with the Helsinki declaration.

2.2 | Subjects

Subjects were recruited at Silkeborg Regional Hospital, Denmark, from August to September 2017. Eligibility criteria for the study included patients older than 18 years and American Society of Anaesthesiologists (ASA) score 1-3 who were scheduled for cemented, unilateral, primary TKA with spinal anaesthesia. The exclusion criteria were inability to cooperate, non-Danish speakers, pregnancy, diabetes, reduced sensation on the lower limb, daily intake of opioids and contraindication to any drug used in the study.

Editorial comment

In this preliminary feasibility study, the authors tested this popliteal plexus intervention for effects which would be used to help design a larger higher powered clinical trial of possible beneficial effects of this type of regional anaesthesia.

2.3 | Anaesthesia

Subjects were monitored with continuous electrocardiography, non-invasive blood pressure measurement and pulse oximetry. All patients underwent spinal anaesthesia with bupivacaine 10 mg. Intraoperative propofol sedation was used at the discretion of the attending anaesthetist.

Acetaminophen 2000 mg and ibuprofen 400 mg were administered orally to all patients 1 hour prior to surgery in the absence of contraindications. After surgery, acetaminophen 1000 mg and ibuprofen 400 mg were administered orally 4 times daily unless contraindicated. Glucocorticoids and opioids were not allowed in the study observation period.

2.4 | Surgery

TKA was performed by 2 orthopaedic surgeons, who inserted bi- or tricompartmental prostheses using a standard medial parapatellar approach. A thigh tourniquet was not employed.

2.5 | Study interventions

2.5.1 | Femoral triangle blockade

Prior to FTB, the intersection of the medial borders of the sartorius and adductor longus muscles was identified ultrasonographically (Figure 1A). This sonoanatomical landmark indicates the apex of the femoral triangle and the proximal end of the adductor canal.[9-12] The transducer was slid 2-5 cm proximally and the femoral artery was visualised in a short-axis view. The nerve block needle was inserted from the lateral end of the transducer and advanced in-plane to the endpoint of injection anterolateral to the femoral artery, where the hyperechoic saphenous nerve could be visualised.[5]

2.5.2 | Popliteal plexus blockade

Prior to PPB, the proximal end of the adductor canal was identified as described above. The transducer was slid distally along the femoral artery until the artery deviated away from the sartorius muscle in the distal part of the adductor canal towards the adductor

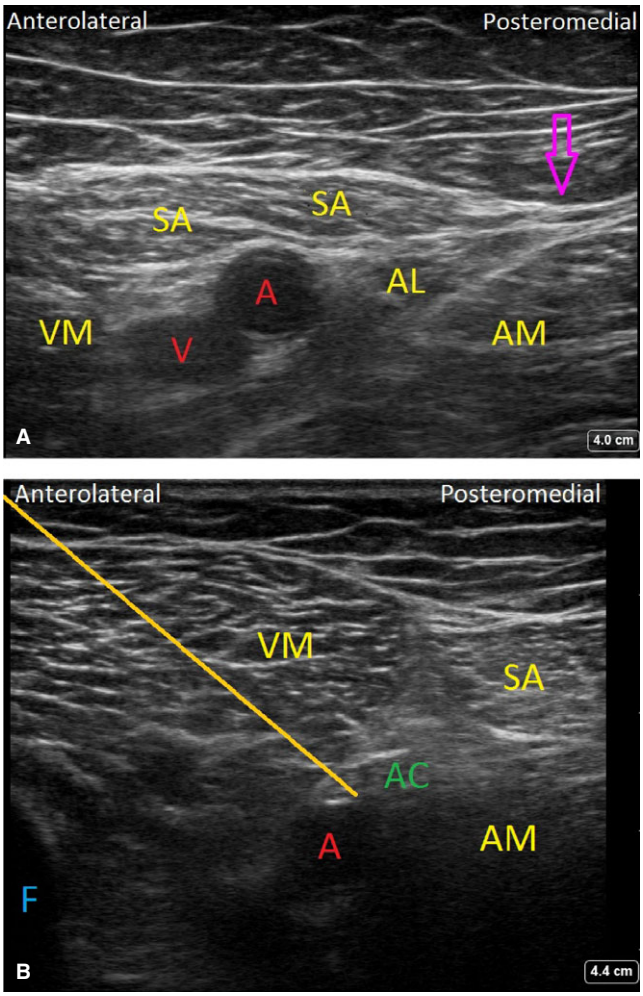

FIGURE 1 A, The proximal end of the adductor canal. The intersection of the medial borders of the sartorius (SA) and adductor longus (AL) muscles defines the apex of the femoral triangle (magenta arrow) and is a proxy marker of the proximal end of the adductor canal. The femoral artery (A) and vein (V) are located in the proximal, superficial end of the adductor canal. Adductor magnus muscle (AM). Vastus medialis muscle (VM). B, The distal end of the adductor canal. The popliteal plexus block via injection in the distal end of the adductor canal (AC). The nerve block needle pierces the vastus medialis muscle (VM) and the endpoint of injection (the tip of the orange line) is adjacent to the femoral artery (A) between the vastus medialis muscle and the adductor magnus muscle (AM). The Sartorius muscle (SA). The femoral bone (F) [Colour figure can be viewed at wileyonlinelibrary.com]

hiatus. The nerve block needle was inserted from the anterolateral end of the transducer and advanced in-plane through the medial vastus muscle. The endpoint of injection was inside the distal end of the adductor canal close to the adductor hiatus. The injection was adjacent to the femoral artery, between the medial vastus muscle and the adductor magnus muscle (Figure 1B).

The FTB and the PPB were each carried out with 10 mL of local anaesthetic mixture, containing 50 mg of bupivacaine and 0.05 mg of epinephrine.

One experienced anaesthetist (CR) performed all the peripheral nerve blocks using a Sonosite X-porte system (Sonosite, Bothell, WA, USA) and either a linear array transducer (HFL 50; Sonosite) or a curved array transducer (C60xp; Sonosite). An 80 mm nerve block needle (Ultraplex 360; B.B. Braun, Melsungen, Germany) was used. Both nerve blocks were carried out with the patient in the supine position.

2.6 | Outcome measures

The primary outcome was the proportion of subjects reporting pain above NRS 3 within the observation period, who had a reduction in pain score to NRS ≤3 within 1 hour after PPB. The end of injection of the FTB was defined as femoral triangle block time 0 (FTB_{t0}). The observation period started at FTB_{t0}. The end of the observation period was defined as 3 hours after the return of normal cutaneous sensation on the lateral aspect of the operated leg.

Secondary outcomes included the following (1-6): (1) proportion of subjects reporting pain score above NRS 3 within the observation period, (2) onset time for the popliteal plexus blockade, (3) frequency of subjects with onset of significant pain (NRS >3) prior to return of normal cutaneous sensation, (4) frequency of subjects with onset of significant pain (NRS >3) after the return of normal cutaneous sensation, (5) the effect of the PPB on the cutaneous sensation on the lateral aspect of the lower leg, (6) the effect of the PPB on the isometric muscle strength of the dorso- and plantarflexors of the ankle joint.[13]

2.7 | Assessment of outcomes

The subjects received an FTB on arrival at the post-anaesthesia care unit (PACU) before the spinal anaesthesia had subsided. The cutaneous sensation on the lateral thigh and on the lateral lower leg on the operated side was assessed with a neuropen (Medisave, Weymouth, UK) every 15 minutes after FTB_{t0} (normal sensation = 2, reduced sensation = 1, no sensation = 0). The NRS pain score (0 = no pain, 10 = worst pain imaginable) was reported every 15 minutes after FTB_{t0} until either pain scored NRS >3 or completion of the observation period without significant pain.

2.7.1 | NRS >3 during the observation period

If a subject reported a pain score of NRS >3, a PPB was carried out. Prior to the PPB, the location of pain was registered as pain in the anterior, the posterior, the medial, or the lateral aspect of the knee, deep knee pain, pain in the thigh or diffuse pain. The end of injection of the PPB was defined as popliteal plexus block time 0 (PPB_{t0}). The pain score (NRS 0-10) and the cutaneous sensation (0-2) on the lateral side of the operated leg were assessed every 5 minutes after PPB_{t0} until NRS ≤3 or a maximum of 60 minutes after PPB_{t0}.

The onset time for the popliteal plexus blockade was defined as the time interval from PPB_{t0} until pain was ≤NRS 3. Only subjects with reduction in pain ≤NRS 3 after PPB_{t0} were included in the estimate of the onset time for the popliteal plexus blockade.

The frequencies of subjects with onset of significant pain (NRS >3) either prior to or after the return of normal cutaneous sensation

on the lateral aspect of the operated leg were only reported for subjects who developed pain NRS >3 during the observation period.

The effect of the PPB on the cutaneous sensation on the lateral aspect of the lower leg was defined as the frequency of subjects with PPB, who had a reduction in cutaneous sensation score (0-2) on the lateral aspect of the operated leg after the spinal anaesthesia had subsided.

Dorsal and plantar ankle flexion was measured as maximum isometric contraction preoperatively and 60 minutes after PPB_{t0}. During the strength test a handheld dynamometer was kept immobile, while the patient performed maximum voluntary isometric contraction (MVIC) of the foot during 5 seconds in order to produce maximum pressure of the foot against the dynamometer. The highest value of 3 consecutive MVIC measurements, separated by a minimum of 30 seconds, was registered for both dorsal and plantar ankle flexion.

The effect of the PPB on the isometric muscle strength of the ankle dorsal and plantar flexors was defined as a reduction in muscle strength of the ankle dorsal and plantar flexors based on paired comparison of the muscle strength values before and after PPB.

2.7.2 | NRS ≤3 during the observation period

The NRS was reported every 15 minutes after FTB_{t0} until the end of the observation period. The subjects who did not present pain during this follow-up period reported if the NRS pain score exceeded 3 within the first 24 hours after FTB_{t0} as well as the location of the pain (see above).

Serious adverse events observed during the trial would be reported.

2.8 | Data capture

Data were collected by the anaesthesiologist who performed the nerve blocks.

2.9 | Sample size estimation

Prior to trial start, we estimated that 10 subjects with TKA, spinal anaesthesia, FTB and pain score above NRS 3 (NRS 0-10) would be sufficient for a crude assessment of the effect of a supplemental PPB. Consequently, we included subjects until the predefined number was obtained.

2.10 | Statistical analysis

Statistical analysis was conducted with STATA 14 (Stata Corp, College Station, TX, USA). Continuous variables with normal distribution were presented as mean (standard deviation and confidence interval). Normality of distribution was tested with histograms and QQ-plots. Nonparametric distributions were presented as median (IQR, interquartile range). Paired comparison of non-Gaussian continuous variables (isometric muscle strength) was carried out with the Wilcoxon signed rank test.

3 | RESULTS

Seventeen subjects were enrolled per protocol. There were no drop-outs. Demographics are shown in Table 1.

Ten out of 17 subjects with TKA, spinal anaesthesia and an FTB experienced pain above NRS 3 (NRS 5.5 [IQR 4-8]) and subsequently received a PPB. All 10 subjects (100%) experienced reduction in pain score to NRS 3 or less (NRS 1.5 [IQR 0-3]) after PPB within 8.5 (95% CI 6.8-10) minutes. The pain was located deep inside the knee (n = 6) or at the posterior aspect (n = 4) of the knee. Four subjects complained of a mild pain (NRS 1-2) in the proximal end of the surgical incision and 1 subject experienced a mild pain (NRS 2) at the lateral aspect of the knee after onset of the PPB. One subject experienced an initial reduction in pain (NRS <3) after PPB followed by a reappearance of pain (NRS >3) located at the lateral aspect of the knee. Three subjects with pain above NRS 3 had complete pain relief (NRS = 0) within 1 hour after PPB_{t0} without any supplemental analgesia.

Seven of the 17 subjects (41%) did not develop pain above NRS 3 within the observation period. Six of these 7 subjects eventually developed pain above NRS 3 at 683 (95% CI 457-908) minutes after FTB_{t0}. The time from return of normal cutaneous sensation on the lateral aspect of the operated leg to development of significant pain in this group was 423 (95% CI 222-655) minutes. Five of these subjects reported pain in the anterior aspect of the knee and 1 subject reported pain in the posterior aspect of the knee. Only 1 of the 17 subjects did not present significant pain (ie, NRS >3) at any time during the first 24 hours after the FTB.

Fifty per cent of the subjects with PPB had a reduction in the cutaneous sensation on the lateral side of the lower leg: 2 subjects had a reduction in cutaneous sensation from 1 to 0, and 3 subjects had a reduction in sensation score from 2 to 1. The muscle strength tests are listed in Table 2.

No adverse events were observed.

TABLE 1 Patient characteristics (n = 17)

	FTB + PPB (n = 10)	FTB (n = 7)
Age (y)	69 (8.3)	69 (8.3)
Sex (F/M)	4/6	2/5
BMI (kg/m^2)	28.6 (3.6)	27.6 (3.3)

BMI, body mass index; F, female; FTB, femoral triangle block; M, male; PPB, popliteal plexus block.
Values are presented as mean (SD) or count.

TABLE 2 Isometric muscle strength test

	Before PPB	After PPB	*P*
Strength of dorsal ankle flexion (N)	84.3 (26.5)	74.4 (17.9)	.09
Strength of plantar ankle flexion (N)	111.7 (27.8)	104.7 (26.5)	.2

PPB, popliteal plexus block.
Values are presented as mean (SD).

4 | DISCUSSION

This non-randomised, unblinded feasibility study indicates that a supplemental PPB possibly provides effective pain relief in subjects having a FTB after TKA.

The observed clinical effects of the supplemental PPB on deep knee pain and pain from the posterior aspect of the knee are in agreement with the findings in a recently published dissection study from our research group.[8] In this dissection study, we observed a spread of 10 mL dye from the distal end of the adductor canal into the popliteal fossa with consistent colouring of the PP and the posterior obturator nerve.[8] Goffin et al[14] observed spread to the sciatic nerve after injecting 20 mL of dye in the distal part of the adductor canal. In this study, the motor strength of dorsal and plantar ankle flexors was unchanged after injecting 10 mL of local anaesthetic in distal part of the adductor canal. Moreover, we did not observe spread of a similar volume of injectate to the sciatic nerve in our recent dissection study.[8] Thus, the risk of spread of injectate from the distal part of the adductor canal to the sciatic nerve might be volume dependent.

It can be speculated that some of the subjects without clinically significant pain (NRS $\leq$3) had spread of injectate from the femoral triangle throughout the adductor canal and into the popliteal fossa with concomitant anaesthesia of the PP. However, in our recent dissection study, we did not observe any distal spread of injectate into the popliteal fossa after injection of 10 mL of methylene blue in the distal part of the femoral triangle.[8] Furthermore, we have previously observed a consistent significant analgesic effect of combining an FTB with a subinguinal obturator nerve block vs standalone FTB after TKA.[5] Consequently, it is unlikely that 10 mL of local anaesthetic injected in the FTB would spread distally throughout the adductor canal to the popliteal fossa in order to anaesthetise the genicular branches of the PP. In another study, 20 mL of contrast was injected in the femoral triangle on volunteers and the distal spread of the injectate in the adductor canal was assessed by MRI.[15] However, the assessment of the distal spread of the injectate was limited to the insertion of the adductor longus muscle to femoral bone, which is in the proximal part and not in the distal part of the adductor canal.[9-11,15] Approximately 40% of the subjects in this feasibility study experienced mild pain (ie, NRS 3 or below) with an FTB and no supplemental PPB after TKA. According to the results from our previous clinical and dissection studies,[5,8] we would have expected a lower percentage of subjects, who experienced mild pain after TKA and an FTB. This could be due to sampling error due to the small sample size.

The internal validity of the present study was limited by the lack of a control group, randomisation and blinding. The primary purpose of the present study was to generate the information needed for an optimal design and power calculation of a planned randomised controlled double-blinded trial, which would be required for unbiased assessment of the selective effect of the PPB on pain after TKA. Afterwards, studies would be warranted for comparison of the analgesic effect of a PPB vs other regional analgesic techniques for relief of the posterior pain after TKA such as local infiltration analgesia or selective blockade of the obturator nerve and sciatic nerve.

In conclusion, this unblinded, non-randomised feasibility study has generated data in support of the research idea, that a supplemental PPB provides effective and sizable reduction in pain in subjects with an FTB after TKA in spinal anaesthesia. This hypothesis needs to be assessed by future randomised controlled trials.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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