Effect of Adductor Canal Block Versus Femoral Nerve Block on Quadriceps Strength, Mobilization, and Pain After Total Knee Arthroplasty
A Randomized, Blinded Study

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Background and Objectives: Total knee arthroplasty (TKA) is often associated with severe pain. Different regional anesthetic techniques exist, all with varying degrees of motor blockade. We hypothesized that pain relief provided by the adductor canal block (ACB) could increase functional muscle strength.

Methods: We included 50 TKA patients with severe movement-related pain; defined as having visual analog scale pain score of greater than 60 mm during active flexion of the knee. The ACB group received an ACB with ropivacaine 0.2% 30 mL and a femoral nerve block (FNB) with 30 mL saline. The FNB group received an ACB with 30 mL saline and an FNB with ropivacaine 0.2% 30 mL. We compared the effect of the ACB versus FNB on maximum voluntary isometric contraction of the quadriceps muscle relative to a postoperative baseline value. Secondary end points were differences between groups in ability to ambulate and changes in pain scores (Clinicaltrials.gov identifier NCT01922596).

Results: After block, the quadriceps maximum voluntary isometric contraction increased to 193% (95% confidence interval [CI], 143–288) of the baseline value in the ACB group and decreased to 16% (95% CI, 3–33) in the FNB group with an estimated difference of 178% (95% CI, 136–226), P < 0.0001. Pain scores were similar between groups. Before block, 2 of 25 patients in each group were unable to perform the Timed-Up-and-Go test; after block, this number increased to 7 of 25 in the FNB group and decreased to 0 of 25 in the ACB group.

Conclusion: Adductor canal block provides a clinically relevant and statistically significant increase in quadriceps muscle strength for patients in severe pain after TKA.

Total knee arthroplasty (TKA) is often associated with severe acute postoperative pain, despite a comprehensive multimodal analgesic regimen, and 25% to 40% of patients will experience severe movement-related pain the first or second postoperative day. Severe pain is not only excruciating to the patients, but it also hinders mobilization, thereby increasing the risk of potentially severe immobility-related complications. Different regional techniques are in use to provide analgesia. Especially the femoral nerve block (FNB) is a well-established treatment and by many considered as the criterion standard. However, the FNB is followed by a substantial reduction in quadriceps muscle strength, thereby delaying mobilization. Furthermore, the FNB has been associated with the risk of falling. Different strategies, to minimize the reduction in quadriceps strength after the FNB, is being pursued, but so far with discouraging results, and it seems unlikely that a “recipe” that will preserve muscle function and still provide adequate analgesia will be found.

The adductor canal block (ACB) is a relatively new block. A single dose of local anesthetic in the adductor canal, not only blocks the largest sensory branch of the femoral nerve, the saphenous nerve, but also the medial femoral cutaneous nerve and probably articular branches of the obturator nerve and the nerve to the vastus medialis, a motor nerve but also the second largest sensory branch of the femoral nerve. As mainly sensory nerves are targeted, except the nerve to the vastus medialis, it results in less reduction of quadriceps muscle strength in healthy volunteers, compared with the FNB.

Even though no noninferiority trials comparing the analgesic effects of the FNB and the ACB exist, placebo-controlled trials have found the analgesic effect of the ACB comparable to the effect seen after FNB. Two recently published retrospective cohort studies and a blinded, randomized comparator study support this assumption. In the comparator study, the authors found that the ACB preserved quadriceps strength better than the FNB, compared with a preoperative baseline. However, quadriceps muscle strength is greatly reduced after TKA per se and because some of the reduction is caused by pain-mediated inhibition of voluntary contraction, we hypothesized that pain relief provided by an ACB could actually increase functional muscle strength. This hypothesis was generated based on our experience from a previous study in which we observed an increase in mobility in patients who were in severe pain before receiving an ACB. We have included 2 videos where a patient is asked to raise her leg from the bed before an ACB (Video, Supplemental Digital Content 1, http://links.lww.com/AAP/A128) and 10 minutes after the ACB (Video, Supplemental Digital Content 2, http://links.lww.com/AAP/A129).

The aim of this study was therefore to examine the effect of the ACB on postoperative muscle strength, with a postoperative preblock baseline using the FNB as a comparative. The primary end point was the difference between groups, at 2 hours after block in maximum voluntary isometric contraction (MVIC) of...
the quadriceps femoris muscle expressed as a percentage of the baseline value. Secondary outcomes were the ability to ambulate, evaluated by the Timed-Up-and-Go (TUG) test, and pain scores at rest, during passive knee flexion and during the TUG test.

**METHODS**

**Patients and Design**

This single-center, randomized, blinded, placebo-controlled trial was approved by the Danish Medicines Agency (EudraCT no. 2012-004554-28), the local Regional Ethics Committee (H-4-2012-157), and the Danish Data Protection Agency. The study was prospectively registered at EudraCT registration. In addition, the study was registered at ClinicalTrials.gov (NCT01922596) after inclusion of the first patient, because we became aware that some journals do not accept an EudraCT registration. The information regarding end points and inclusion criteria is identical to the prospective registration at EudraCT. The Copenhagen University Hospital Good Clinical Practice Unit monitored the trial. The study was carried out in accordance with the Helsinki Declaration, and data are presented in accordance with the CONSORT statement.18 From March 2013 to November 2013, patients who had undergone elective, unilateral, primary TKA at Copenhagen University Hospital, Gentofte Hospital, Denmark, were screened on the day of surgery, but specific inclusion criteria were not revealed. Inclusion criteria were as follows: unilateral TKA and visual analog scale (VAS) pain score greater than 60 mm during active 45-degree flexion of the knee, hip flexion 90 degrees, hip abduction 30 degrees, knee flexion 30 degrees, and ankle plantarflexion 90 degrees. Exclusion criteria were inability to cooperate; inability to understand, read, and speak Danish; medicine or alcohol abuse; and allergy to ropivacaine. Written informed consent was obtained from all subjects prior to enrollment.

**Surgery, Anesthesia, and Preoperative and Postoperative Analgesia**

Total knee arthroplasty was performed with insertion of tricompartmental prostheses using a standard medial parapatellar approach. Cruciate-substituting as well as cruciate-retaining designs were used. Surgery was performed in a bloodless field using a femoral tourniquet. At the end of surgery, a compression bandage to toes to midtibia was applied. Surgery was performed under spinal anesthesia with 10 to 15 mg bupivacaine 0.5% or under general anesthesia with propofol and remifentanil.

All patients had received a standardized multimodal analgesic regimen (unless contraindicated): preoperatively: oral celecoxib 400 mg, acetaminophen 1 g, and gabapentin 600 mg; intravenously: local infiltration analgesia with 150 mL of ropivacaine 0.2% with epinephrine (10 µg/mL) performed as described by Kerr and Kohan;17 postoperatively: oral acetaminophen 1 g every 4 hours, ibuprofen 400 mg every 3 hours, gabapentin 300 mg (7.50 AM) and 600 mg (10:00 PM), and opioids as required. Slow-release opioids were administered at 7:00 AM and 7:00 PM according to age, weight, and concomitant medication. Oral immediate-release opioids were self-administered by the patients. During the 2-hour study period, the patients could ask for supplemental opioids (none did). During the screening/inclusion period, different opioids were used in the ward; therefore, opioid consumption is presented as an equivalent dose of oral morphine. To avoid influence of other recently administered analgesics, a minimum of 1 hour should pass between administration of medication and evaluation of eligibility for inclusion.

**Randomization and Blinding**

The pharmacy performed a random allocation sequence and prepared 50 consecutive boxes containing the study medication for each patient. Each box contained 2 smaller boxes, one marked “ACB” and the other marked “FNB.”

For the ACB group, the “ACB” box contained 3 × 10-mL containers with ropivacaine 0.2% and the “FNB” box 3 × 10-mL containers with isotonic saline. For the FNB group, the “ACB” box contained 3 × 10-mL containers with isotonic saline and the “FNB” box 3 × 10-mL containers with ropivacaine 0.2%.

Ropivacaine and isotonic saline are visually indistinguishable, and the containers were of identical appearance.

**Interventions**

Baseline values (VAS pain scores, MVIC quadriceps, MVIC adductors, and TUG test) were obtained shortly before block performance. First, patients received an ACB with 30 mL of study medication from the corresponding box, marked “ACB,” immediately followed by an FNB with injection of 30-mL study medication from the “FNB” box. Hence, we ensured that all patients received a blinded, active treatment. The blocks were performed during real-time ultrasonography using a portable machine (GE Logiq e, Waukesha, Wisconsin) with a high-frequency linear transducer. The adductor canal was identified in short-axis view approximately at the midhight level. A 22-gauge, 80-mm Pajunk (Pajunk Medizintechnologie GmbH, Germany) needle was inserted in plane with the transducer with the tip of the needle located anterior to the superficial femoral artery, deep to the sartorius muscle, between the vastus medialis of the quadriceps muscle and the adductor longus muscle. The FNB was performed in plane proximal to the division of the femoral artery. All blocks were performed by the primary investigator (U.G.).

**Outcomes and Assessments**

Maximum voluntary isometric contraction is expressed as a percentage of baseline values 2 hours after block. The primary end point was difference between groups in quadriceps MVIC. Secondary outcomes were difference between groups in hip adductors MVIC, as well as VAS pain scores at different time points at rest and during 45-degree passive flexion of the knee, worst pain during the TUG test, and time to perform the TUG test. Assessments were performed at baseline (T0) and at the end of the study period (T120), in the following sequence: pain at rest, pain during 45-degree passive flexion of the knee, MVIC adductors, MVIC quadriceps, and TUG test (time to perform and worst pain).

We evaluated muscle strength as MVIC with a handheld dynamometer (Lafayette Instrument Company, Lafayette, Indiana), which is considered a reliable and valid instrument.22 Quadriceps muscle strength was evaluated with the patient in a seated position with the knee flexed approximately 60 degrees and both feet off the floor. The dynamometer was placed perpendicular to the tibial crest 5 cm proximal to the medial malleolus. Hip adductor strength was evaluated with the patient in the supine position with the operated leg abducted approximately 30 degrees. The patients were instructed to take 2 seconds to reach maximum force and hold this for 3 seconds. For each assessment, 3 measurements were done with a 30-second pause between, and the mean values of these were used for comparisons.

The TUG test measures the time it takes a patient to get up from a chair, walk 3 m, and return to the sitting position in the chair.21 All patients used a high 4-wheel walker with arm support. The patients were instructed to report the worst VAS pain score experienced during the TUG test.
The success rate of the block was assessed by testing for sensation of cold in the saphenous area of the lower leg prior to the first block and at the end of the study period. In conjunction with a physiotherapist, the primary investigator (U.G.) did all the assessments.

**Statistical Analysis**

A difference of 20%, between the groups, in quadriceps MVIC was chosen as clinically relevant as a side-to-side difference.
of 10% is normal in healthy individuals.\textsuperscript{22} We assumed an SD of 20% in quadriceps MVIC. With $\alpha = 0.05$ and a power of 90%, $2 \times 22$ patients would be required using standard sample power calculations for difference in mean between 2 independent groups. To account for the uncertainty in predicting the actual SD, $2 \times 25$ patients were included. Data were analyzed using IBM SPSS Statistics version 20.

Categorical data (number of patients able to mobilize and success rate of the block) are only reported as actual numbers and not compared using statistical tests because they were not end points. All end points are continuous data; changes in MVIC were found to be skewed (visual examination of histograms, normal Q-Q plots, box plot, and Shapiro and Wilk test; $P < 0.05$) and hence analyzed as nonparametric data using the Mann-Whitney test. Maximum voluntary isometric contraction data are presented as median and 95% confidence interval (95% CI) change from baseline, expressed as a percentage (100% represents “no change”). The treatment effect (differences in MVIC between groups) was quantified using the Hodges-Lehman estimator with a constructed 95% CI. The VAS pain scores were measured repeatedly, and thus, a linear mixed model was applied with treatment, time, and the interaction treatment $\times$ time included in the model. The model has time as a repeated effect with a first-order autoregressive covariance structure [AR(1)]. Baseline values were included as a covariate to compensate for baseline differences.

Data Handling

After inclusion of the last patient, all data were entered into a spreadsheet and checked for typing errors by 2 investigators. The pharmacy that performed the randomization delivered a list, assigning each patient to 1 of 2 primary groups (A and B) without revealing the identity of the groups. After data analysis was completed and conclusions were drawn, the pharmacy reported which of the primary groups corresponded to the ACB group and the FNB group, respectively.

RESULTS

Of 226 patients assessed for eligibility, 50 were included and randomized. One patient in the FNB group had a baseline quadriceps MVIC value of 0.0 making a calculus of percentage impossible, so 49 patients were analyzed for the primary end point (Fig. 1). The groups were similar with respect to demographics and perioperative data (Table 1).

Quadriceps MVIC

Quadriceps MVIC was significantly higher in the ACB group, with a median change from baseline of 193% (95% CI,
143%–288%), compared with 16% (95% CI, 3%–33%) for the FNB group. The estimated median difference in postblock MVIC between the ACB group and FNB group was 178 percentage points (95% CI, 136–226 percentage points) of the preblock MVIC, \( P < 0.0001 \) (Fig. 2). Individual patients’ absolute values are shown in Figure 3; in the ACB group, all patients but 3 (green dots below the dotted line) increased in quadriceps MVIC compared with none in the FNB group (red dots below the dotted line). In the ACB group, 12 of 25 more than doubled their strength compared with baseline.

**Adductors MVIC**

There was no significant change in adductors MVIC between the groups. There were though a tendency toward an increase in the FNB group with a median change from baseline of 139% (95% CI, 113%–154%), compared with 107% (95% CI, 99%–125%) for the ACB group with an estimated difference of 21% (95% CI, −1% to 42%), \( P = 0.06 \) (Fig. 2).

**TUG Test**

Two patients (8%) in the ACB group and 2 (8%) in the FNB group were unable to perform the test at baseline because of pain. At T120, all patients in the ACB group were able to perform the test, whereas 7 (28%) in the FNB group could not; 6 were unable to stand up from the sitting position because of muscle weakness, and 1 became very dizzy and nearly fell, and the assessors stopped the test.

At T120, patients performed the TUG test significantly faster in the ACB group = 32 seconds (95% CI, 27–37 seconds), compared with the FNB group = 52 seconds (95% CI, 41–62 seconds), with a mean difference of 20 seconds (95% CI, 9–30 seconds), \( P = 0.001 \). Compared with baseline, patients in the ACB group performed the test significantly faster at T120 = 11 seconds (95% CI, 6–16 seconds), \( P = 0.001 \). Compared with baseline, patients in the FNB group tended to perform the test slower at T120 = 3 seconds (95% CI, −5 to 11 seconds), \( P = 0.5 \).

No significant differences between groups were found for worst pain during the test. At baseline pain scores were 69 mm (95% CI, 61–77 mm) in the ACB group, compared with 67 mm (95% CI, 59–75 mm) in the FNB group. At T120, this declined to 37 mm (95% CI, 28–46 mm) and 42 mm (95% CI, 31–53 mm) in the ACB and FNB groups, respectively.

**Pain at 45-Degree Passive Knee Flexion**

There were no significant differences, between groups, at any time points (Fig. 4). At T120, a mean VAS score of 20 mm (95% CI, 13–27 mm) was found in the ACB group and 23 mm (95% CI, 16–30 mm) in the FNB group compared with baseline values of 66 mm (95% CI, 59–73 mm) and 65 mm (95% CI, 58–72 mm), respectively.

**Pain at Rest**

There were no significant differences, between groups, at any time points (Fig. 5). At T120, a mean VAS score of 9 mm (95% CI, 4–14 mm) was found in the ACB group and 9 mm (95% CI, 4–14 mm) in the FNB group compared with baseline values of 35 mm (95% CI, 30–40) and 35 mm (95% CI, 30–40), respectively.

**FIGURE 3.** Effect of ACB and FNB on quadriceps femoris muscle strength assessed as maximum voluntary isometric contraction (MVIC) in kilograms. Each dot represents individual patients preblock and postblock MVIC values. Dots above or under the dotted black line represent patients who experienced an increase or a decrease, respectively, in muscle strength after the block. All patients in the FNB group experienced a decrease, compared with 3 patients in the ACB group.
Success Rate of the Blockade

All patients, but 1 (missing data), were tested for the ability to sense cold in the saphenous area prior to the first block. One patient (ACB group) did not have any sensation in this area and could therefore not be included in the evaluation of block success rate. The success rate, assessed as loss of sensation of cold at the end of the study period, was 100% (95% CI, 93%–100%).

DISCUSSION

The aim of this study was to compare the effect of ACB versus FNB on quadriceps strength relative to a preblock baseline value. As expected, the FNB group experienced a pronounced decline to 16% of baseline values. On the contrary, patients in the ACB group almost doubled their quadriceps strength. To our knowledge, this is the first study to show that a peripheral nerve block can increase muscle strength, a finding contradicting former beliefs that nerve blocks are associated with motor paralysis. A probable explanation for the increase in MVIC quadriceps seen in the ACB group is that pain relief decreases the centrally mediated inhibition of the voluntary contraction, but without the peripheral motor inhibition seen with the FNB.

Only 3 patients in the ACB group experienced a decline in quadriceps strength. However, they retained approximately 85% of their baseline value. Therefore, we regard it as unlikely that this decline is due to a spread to the femoral nerve; more likely, it is due to simple variance in the measurements.

Whether the difference in quadriceps strength is clinically relevant is a question of great importance as quadriceps strength is a factor in balance, gait, and the occurrence of falls23 and TKA on its own profoundly weakens quadriceps strength.16,17 Although not a planned outcome, the finding that 2 patients in each group were unable to perform the TUG test at baseline compared with 7 in the FNB group and 0 in the ACB group at the end of the study suggests that these changes in quadriceps strength have a great impact on the ability to ambulate. For those patients able to mobilize, the time to perform the TUG test decreased by 11 seconds (25%) in the ACB group compared with a small increase in the FNB group. As we used a high 4-wheel walker for the TUG test, to minimize the risk of falling, we believe the differences found in ability to ambulate would have been even greater without this aid, as the nonsurgical leg can compensate for the surgical leg.24

As always, interpretation of secondary outcomes must be made with caution. Especially the finding of no significant differences in pain scores is sometimes mistaken for equivalency. Even though the omission of a placebo group makes the interpretation of VAS pain scores difficult, it is interesting that both groups showed a pronounced analgesic effect compared with baseline, and no significant differences between groups were observed. This is on par with results from other studies.13-15 Because a patient with an FNB has a visually distinct knee flexion, compared with a patient with an ACB, an evaluation of active flexion of the knee most likely would have unblinded the study, prior to evaluation of the primary end point. Therefore, the repeated measurements only evaluated pain at rest and during passive flexion. The distinction between active and passive flexion is important when comparing the analgesic effect to other studies and could explain why the analgesic effect found in this study is quite

![Figure 4. Mean VAS pain score during 45-degree passive flexion of the knee. The whiskers indicate 95% CI. No statistically significant differences between groups were observed.](https://rapm.bmj.com/content/40/1/8)
noticeable. However, passive flexion of the knee probably tells us little about movement-related pain; it is therefore comforting that pain scores during the TUG test also decreased substantially.

Our study has several limitations. Clearly, because we evaluated only the immediate effects, the study tells us nothing about the duration of the effects or whether these effects lead to better long-term functional outcome. The omission of a placebo group can be criticized, but was chosen for ethical reasons. Because we were looking at patients in severe pain, despite a comprehensive multimodal analgesic regimen, we found it problematic to have a placebo group. The decision to include only patients in severe pain makes the study less inferential. Thus, we do not know if the increase in MVIC quadriceps is seen only in patients with severe pain.

The volume of 30 mL is controversial, and many clinicians would never use this large a volume, especially not for an FNB. Because we regard the ACB as a high-volume block, we found it essential to use this volume for the ACB and chose the same volume for the FNB for several reasons. First, it is well established that small volumes and even low concentrations of local anesthetics have an immense effect on quadriceps strength, so the large volume applied in the present study most likely made no major difference in the primary end point. Second, we need not consider a difference in a possible systemic effect. Third, considering the large volume, it is very unlikely that we did not obtain maximum analgesic effect of the FNB, so the finding of no differences in pain scores between the groups supports the assumption of noninferiority, although secondary end points should not be overinterpreted.

In conclusion, for patients in severe pain after TKA, we demonstrated that the ACB increases quadriceps muscle strength compared with postoperative baseline values. As more patients could be mobilized after the block and with superior functional performance (on the TUG test), this increase is considered clinically relevant. Furthermore, the ACB seems to have a similar analgesic effect to the FNB, both at rest and during mobilization.

Future studies should address if the analgesic effect of the ACB really is noninferior to the FNB, and whether the effect of the ACB on motor strength and mobilization also can be found in a broader population of patients undergoing TKA including those in less severe pain. Furthermore, evaluation of the duration of the effects of the ACB, optimal volumes, concentrations, and administrations (eg, single shot vs catheter, bolus vs infusion) should also be investigated.

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