Adductor Canal Block *versus* Femoral Nerve Block and Quadriceps Strength

A Randomized, Double-blind, Placebo-controlled, Crossover Study in Healthy Volunteers

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ABSTRACT

Background: The authors hypothesized that the adductor canal block (ACB), a predominant sensory blockade, reduces quadriceps strength compared with placebo (primary endpoint, area under the curve, 0.5–6 h), but less than the femoral nerve block (FNB; secondary endpoint). Other secondary endpoints were adductor strength and ability to ambulate.

Methods: The authors enrolled healthy young men into this double blind, placebo-controlled, randomized, crossover study. On two separate study days, subjects received either ACB or FNB with ropivacaine, and placebo in the opposite limb. Strength was assessed as maximum voluntary isometric contraction for quadriceps and adductor muscles. In addition, subjects performed three standardized ambulation tests. Clinicaltrials.gov Identifier: NCT01449097.

Results: Twelve subjects were randomized, 11 analyzed. Quadriceps strength (area under the curve, 0.5–6 h) was significantly reduced when comparing ACB with placebo (5.0 ± 1.0 *vs.* 5.9 ± 0.6, $P = 0.02$, CI: −1.5 to −0.2), FNB with placebo ($P = 0.0004$), and when comparing FNB with ACB ($P = 0.002$). The mean reduction from baseline was 8% with ACB and 49% with FNB. The only statistically significant difference in adductor strength was between placebo and FNB ($P = 0.007$). Performance in all mobilization tests was reduced after an FNB compared with an ACB ($P < 0.05$).

Conclusions: As compared with placebo ACB statistically significantly reduced quadriceps strength, but the reduction was only 8% from baseline. ACB preserved quadriceps strength and ability to ambulate better than FNB did. Future studies are needed to compare the analgesic effect of the ACB with the FNB in a clinical setting.

What We Already Know about This Topic

- Continuous femoral nerve block is commonly used for postoperative analgesia after knee surgery, but results in quadriceps weakness and an increased risk of falling
- Adductor canal block has been advocated as an alternative with perhaps less risk of motor weakness

What This Article Tells Us That Is New

- In healthy volunteers, adductor canal block reduced quadriceps strength by only 8% compared with 49% with femoral nerve block, suggesting that both risk of weakness and falling might be reduced in patients with adductor canal block

THE femoral nerve block (FNB) is often considered as the gold standard for postoperative pain treatment after total knee arthroplasty. Continuous FNBs, however, have been shown to reduce quadriceps muscle strength[1] and are associated with an increased risk of falling postoperatively.[2] Efforts have been made to optimize the continuous FNBs by comparing basal infusion with repeated hourly bolus doses,[1] by investigating the effect of continuous infusions with different concentrations and basal rates, but at equivalent total

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doses,[3] and by reducing the total dose of local anesthetic injected.[4] None of these attempts were successful in reducing the degree of quadriceps muscle block, and reducing the total dose of local anesthetic was followed by insufficient pain relief.[4]

Jenstrup *et al.*[5] reported a favorable effect of the adductor canal block (ACB) on pain during activity and morphine consumption comparable with the results of the FNB, as presented in a recent meta-analysis.[6] In addition, the ACB enhanced mobilization ability compared with placebo, assessed with the Timed-Up-and-Go (TUG) test.[5] The ACB theoretically affects mainly sensory nerves. The only motor nerve traversing the adductor canal is the nerve to the vastus medialis.[7] In addition, the posterior branch of the obturator nerve enters the distal part of the canal,[7] but as the upper part of the adductor magnus is the most distal muscle innervated by this nerve,[8] it seems likely that the motor fibers depart before the nerve enters the canal. In comparison, the FNB affects all four parts of the quadriceps muscle, the pectineus muscle and, although rarely, it might also block the obturator nerve (as part of a 3-in-1-block).

Due to the affection of the vastus medialis muscle the ACB is expected to reduce the quadriceps muscle strength compared with placebo, but to a limited extent compared with the FNB. The ACB and the FNB can also be expected to reduce adductor strength: the ACB by blocking the posterior branch of the obturator nerve, and the FNB by blocking the pectineus muscle and a possibly involvement of the obturator nerve. No study to date has investigated the effect of ACB on muscle strength.

We aimed to investigate the effect of the ACB in healthy volunteers on quadriceps and adductor muscle strength, and the ability to ambulate. We hypothesized that the ACB reduces quadriceps strength to some extent compared with placebo (primary endpoint). Secondary endpoints included the effect of the ACB on quadriceps strength compared with the FNB as an active control, and the effect on adductor strength and ability to ambulate.

Materials and Methods

This prospective, randomized, double blind, placebo-controlled, crossover study was approved by the local Regional Ethics Committee (H-4-2011-057), the Danish Medicines Agency (2011-004285-15), and the Danish Data Protection Agency. The trial was registered (NCT01449097)** and monitored by the Copenhagen University Hospital Good Clinical Practice unit. The study was conducted at the Copenhagen University Hospital, Rigshospitalet, in accordance with the guidelines for Good Clinical Practice and the Helsinki Declarations. Data are presented in accordance with the CONSORT statement.

After obtaining written informed consent, 12 male volunteers were included into the study from October to November 2011. Men aged 18–30 yr, with a body mass index of 18–25, and American Society of Anesthesiologists status I were considered eligible. Exclusion criteria were: intense exercise 24 h before the tests, consumption of opioids or steroids (except oral inhalation) within the last 4 weeks, any drug intake within the last 48 h, pathology or previous surgery or trauma to the lower limb, diabetes mellitus, inability to cooperate, inability to speak or understand Danish, alcohol or drug abuse, or allergy to any drug used in the study.

Interventions

Each subject was investigated on 2 separate study days. At least 72 h had to elapse between 2 experiments in a single subject. On the first day of the study, subjects received an FNB in one limb and an ACB in the other limb. In a double-masked fashion and according to randomization 30 ml of 0.1% ropivacaine was given in one block and isotonic saline in the other. This was reversed on the second day of the study (see Randomization and Blinding). The FNB was performed first (T = 0), shortly followed by the ACB. Subjects were placed in a supine position, with the leg to be blocked abducted 45 degrees in the hip and the knee flexed, so that the heel touched the contralateral knee. Venue 40 ultrasound machine (GE Medical Systems, Wuxi, China) equipped with linear 12 L probe was used in all blocks for needle guidance. No other medication was given during the study period.

Femoral Nerve Block. We employed the technique presented by Murray *et al.*[9] for the FNB. The femoral nerve was clearly visible in all subjects, as was the blocking needle, which was inserted in plane. Hence, it was not necessary to use a nerve stimulator. Thirty milliliters of either local anesthetic or saline was slowly injected with repeated aspiration. The needle tip was repositioned when necessary during injection to assure full spread of the solution around the nerve.

Adductor Canal Block. The linear probe was placed on the medial part of the thigh half way between the inguinal ligament and the patella. The femoral artery was visualized in short axis immediately under the sartorius muscle. After skin preparation with chlorhexidine gluconate and isopropyl alcohol a 22-gauge, 80-mm long insulated needle (Stimuplex D Plus; B. Braun Medical, Melsungen, Germany) was inserted in plane of the probe from lateral direction. The sartorius muscle was transfixed and the needle tip was placed under it just lateral and superficial to the artery. Thirty milliliters of either local anesthetic or saline was then slowly injected with repeated aspiration.

All subjects received both active ACB and FNB during the 2 days of the study, but only one active block at the time. Placebo treatment consisted of saline injected in the block in the opposite limb.

Outcomes

The primary endpoint was the difference in quadriceps strength (calculated as area under the curve for the interval 0.5–6 h) in

** www.clinicaltrials.gov. Accessed September 24, 2012.

limbs receiving ACB compared with placebo. Secondary endpoints included the difference in quadriceps strength in limbs receiving FNB compared with ACB and placebo, the difference in adductor strength between the different treatments, and the difference between ACB and FNB in mobilization tests at 1 and 6 h (TUG test, the 10-m walk test and the 30-s Chair Stand test).

Assessment of Outcomes

Muscle strength was assessed as maximum voluntary isometric contraction (MVIC) with a handheld dynamometer (HHD, Lafayette Instrument, Lafayette, IN). The HHD is considered a reliable and valid instrument for measuring muscle strength.[10] We applied standardized and recommended procedures to assure valid measurements.[11]

Quadriceps strength was measured with the subjects placed in a seated position with the knees flexed 90 degrees and the lower legs hanging free.[12] Although excellent intraclass correlation coefficients have been shown with this setup for quadriceps evaluation in some studies,[12,13] other studies have shown that when measuring the strength of the knee extensors, interrater reliability can be reduced if the strength of the subject overcomes the strength of the tester.[14–17] To eliminate interrater variability, a blinded, single examiner (Ms. Hilsted) performed all assessments. In addition, we used a setup described earlier,[18] using nonelastic strap with Velcro closures to fix the dynamometer for quadriceps evaluation. The Velcro strap was attached to the examination couch and around the patient's ankle, perpendicular to the lower leg. The HHD was placed under the Velcro strap on the anterior tibia, 5 cm proximal to the transmalleolar axis.

For adductor strength evaluation, we applied a validated procedure[19] with the subjects placed in supine position and the ipsilateral leg abducted 30 degrees from the sagittal plane. The HHD was placed on the medial tibia 5 cm proximal to the medial malleolus. A marker was used to mark the correct placement of the HHD and to assure the same placement throughout the day.

We performed three consecutive quadriceps and adductor muscle practice contractions to familiarize the subject with the procedure. Subjects were instructed to take 2 s to reach the maximal effort, maintain this force for approximately 3 s and then relax. A standardized verbal command was issued during the trials ("push-push-push-pause"). The subjects performed three consecutive trials separated by 30-s rest periods, for each muscle at each time point. The mean value was used for calculations. Muscle strengths was assessed preblock, at 30 min, 45 min, and 1, 2, 3, 4, 5, and 6 h postblock.

Mobilization ability was assessed with the TUG test, the 10-m walk test and the 30-s Chair Stand test, preblock and at 1 and 6 h postblock. The TUG test measures the time it takes a person to stand up from a chair, walk a distance of 3 m, and return to the chair. The 10-m walk test measures the time it takes to walk a distance of 10 m as quickly as possible. The 30-s Chair Stand test assesses how many times a person is able to rise from a chair and sit down again in 30 s, with the arms kept crossed over the chest. The mobilization tests have been validated in previous studies.[20–22] No gait aids were allowed during the tests. The tests were only performed if the subject felt that it was possible rise without the risk of falling. Statistical handling of results from subjects who could not be mobilized is described in the Statistical Analysis section.

We tested muscle strength and ability to ambulate in all subjects at 24 h postblock. These tests were only made as a clinical control and the data were not included in the statistical analyses. If full strength was not regained at 24 h, another control was scheduled until the block had subsided completely.

After completion of all assessments at 6-h postblock a blinded observer, not otherwise involved in the study, tested all subjects for loss of cold sensation in the saphenous nerve innervation area, on the medial part of the lower leg.

Randomization and Blinding

The subjects were assigned consecutive numbers upon inclusion into the study. The pharmacy prepared two prepacked boxes for each study participant, one for each study day. Each prepacked box was labeled with the corresponding study day and contained two identical 20-ml containers; one with 0.2% ropivacaine the other with isotonic saline. The two 20-ml containers were labeled ACB and FNB, according to randomization. Ropivacaine and isotonic saline are both transparent liquids and were packed in containers identical in appearance. To obtain a concentration of 0.1% ropivacaine, each 20-ml container of study medication was diluted with 20 ml of isotonic saline in a syringe. Thirty milliliters of diluted study medication was injected in each block.

The subjects received two blocks on each day of the study, one in each limb. The randomization process assured that all subjects received both an active ACB and an FNB during the 2 days of the study, but only one active block at the time, with a placebo block in the opposite limb. All ACBs were placed in the right limb and all FNBs in the left limb on day 1 of the study, with the opposite placement on day 2. This assured that for each participant the active blocks were placed in the same limb on days 1 and 2 of the study (either right or left according to randomization) and that the placebo blocks were in the opposite limb both days of the study.

All investigators and subjects were blinded to treatment. The randomization key was first broken once enrolment of all subjects was completed.

Sample Size

A 25% reduction from baseline in quadriceps MVIC was considered clinically relevant, because a side-to-side difference of 10% is normal in healthy individuals without functional importance.[23,24] On the basis of a previous study,[1] we estimated that the SD of the percent change from baseline would be 18. With $\alpha = 0.05$ and a power of 80%, 10 subjects would be required in this crossover study. To compensate for dropouts, we planned for an inclusion of 12 subjects.

Statistical Analysis

Data were analyzed using SAS version 9.1 (SAS Institute Inc., Cary, NC). Data are presented as mean with SD. The sample size of this study was 12 (less 1 secondary to subject falling), thus limiting the precision with which distributional characteristics can be assessed. Parametric tests were chosen under the assumption that muscle strength and mobilization are physiological parameters that usually are normally distributed. A two-sample *t* test for paired data was used for comparisons between the placebo and ACB, placebo and FNB, and ACB and FNB treatments. At each time point, we used the mean value from the three consecutive trials to calculate the percentile change in MVIC from baseline. For limbs receiving placebo, we used the mean value of days 1 and 2. For comparison of MVIC (in percentage of baseline values) between the treatments, we calculated the area under the curve for the interval 0.5–6 h postblock. We calculated the area under the curve by adding the areas under the curve between each pair of consecutive observations $[(t_2 - t_1)\ (y_1 + y_2)/2]$. Comparisons of MVIC between the treatments were only performed as area under the curve for the interval 0.5–6 h. Comparisons of the ability to ambulate with an ACB *versus* an FNB were performed at 1 and 6 h postblock. Subjects who were unable to perform the mobilization tests obtained a value of zero in the 30-s Chair Stand test, whereas for the TUG and 10-m walk tests we used the highest test score value obtained with each treatment and added 1 s to this score. The nature of the hypothesis testing was two-tailed, and a *P* value of less than 0.05 was considered significant. The 24-h assessments were not part of the statistical analyses. All planned statistical analyses were reported** before inclusion into the study.

Results

Twelve subjects were included and randomized, 11 analyzed. One subject (receiving active FNB) withdrew his consent after a fall episode at 10 h postblock on day 1. The fall resulted in brief involuntary contractions of the muscles of the thigh, which resolved without treatment and sequelae. For subjects' characteristics, see table 1.

The mean quadriceps MVIC (0.5–6 h postblock) was 92% of baseline values in limbs receiving ACB, compared with 51% in limbs receiving FNB, and exceeded baseline values by 6% in limbs receiving placebo (fig. 1). When calculated as area under the curve for the same interval, the quadriceps MVIC was statistically significantly reduced in limbs receiving ACB compared with placebo (5.0 ± 1.0 *vs.* 5.9 ± 0.6, *P* = 0.02, CI: −1.5 to −0.2). Additionally, the quadriceps MVIC was reduced in limbs receiving FNB compared with both ACB (2.5 ± 2.3 *vs.* 5.0 ± 1.0, *P* = 0.002, CI: 1.3–3.9) and placebo (2.5 ± 2.3 *vs.* 5.9 ± 0.6, *P* = 0.0004, CI: 1.9–4.8) (fig. 1).

The mean adductor MVIC (0.5–6 h postblock) was 95% of baseline values in limbs receiving ACB, compared with 90% and 99% in limbs receiving FNB and placebo, respectively (fig. 2). On the basis of calculations of area under the curve, there were no differences in adductor MVIC between limbs receiving ACB *versus* placebo (5.2 ± 0.8 *vs.* 5.5 ± 0.5, *P* = 0.29) or ACB *versus* FNB (5.2 ± 0.8 *vs.* 4.9 ± 0.6, *P* = 0.37). However, there was a statistically significant difference between limbs receiving FNB and placebo (4.9 ± 0.6 *vs.* 5.5 ± 0.5, *P* = 0.007).

All subjects could be mobilized after receiving an ACB (ACB in one limb, placebo in the opposite limb). Conversely, after receiving an FNB (FNB in one limb, placebo in the opposite limb) only 6 of 11 subjects could perform the TUG test at 1 and 6 h postblock (fig. 3), 5 of 11 and 6 of 11 could perform the 10-m walk test (1 and 6 h, respectively, fig. 4), and 6 of 11 and 7 of 11 could perform the 30-s Chair Stand test (1 and 6 h, respectively, fig. 5). Results are presented in table 2. The subjects performed the TUG and the 10-m walk test at 1 and 6 h postblock faster after receiving an ACB compared with an FNB (TUG: *P* = 0.002 and *P* = 0.008, 1 and 6 h, respectively; and 10-m walk test: *P* = 0.005 and *P* = 0.002, 1 and 6 h, respectively). Additionally, the number of times the subject was

Table 1. Subjects' Characteristics

No. of subjects	11
Age, yr	24 ± 2
Height, cm	182 ± 7
Weight, kg	79 ± 6

Values are reported as number of subjects or mean ± SD.

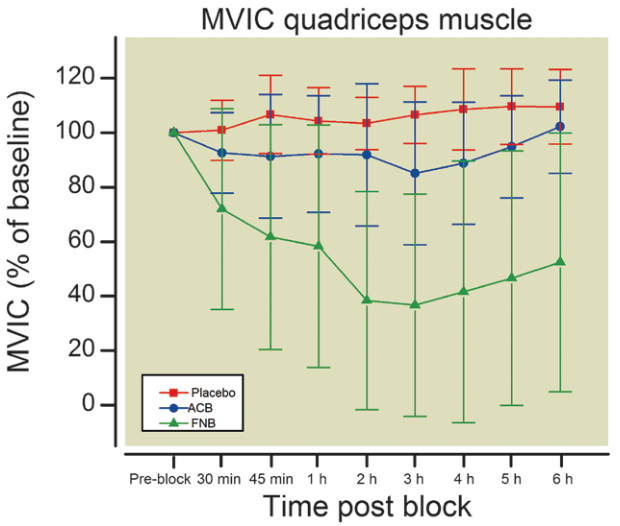

Fig. 1. Effects of the ACB, FNB and placebo on quadriceps muscle strength. Muscle strength was assessed as MVIC calculated as area under the curve for the interval 0.5–6 h postblock (mean ± SD). Quadriceps MVIC was significantly reduced when comparing placebo with ACB (*P* = 0.02), and FNB (*P* = 0.0004), and when comparing ACB with FNB (*P* = 0.002). ACB = adductor canal block; FNB = femoral nerve block; MVIC = maximum voluntary isometric contraction.

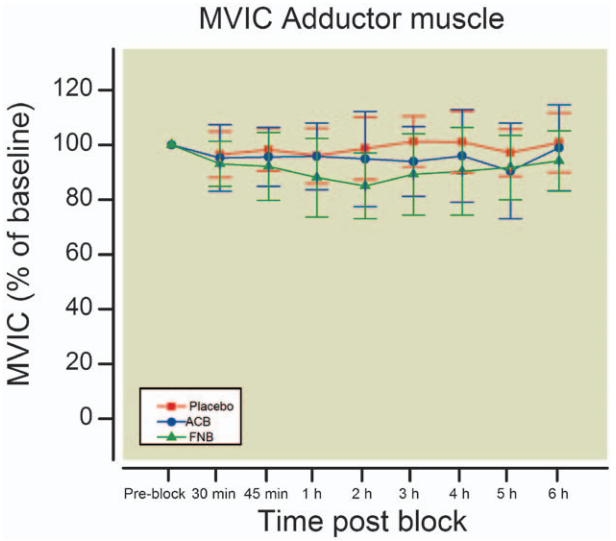

Fig. 2. Effects of the ACB, FNB and placebo on adductor muscle strength. Muscle strength was assessed as MVIC calculated as area under the curve for the interval 0.5–6 h postblock (mean ± SD). The difference in adductor muscle strength between placebo and FNB was statistically significant ($P = 0.007$) but not clinically important. ACB = adductor canal block; FNB = femoral nerve block; MVIC = maximum voluntary isometric contraction.

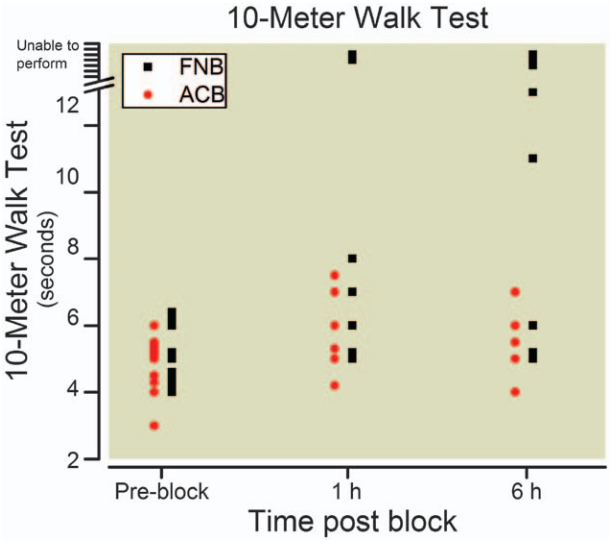

Fig. 4. Effects of the ACB and FNB on mobilization, assessed with the 10-m walk test. Data are expressed as mean ± SD. Subjects who could not be mobilized were assigned the highest test score value obtained with each treatment and 1 s was added to this score. The subjects performed the 10-m walk test at 1 and 6 h significantly faster after receiving an ACB compared with an FNB ($P = 0.005$ and $P = 0.002$, respectively). ACB = adductor canal block; FNB = femoral nerve block.

able to rise and sit during the 30-s Chair Stand test was reduced after the FNB compared with the ACB ($P = 0.007$ and $P = 0.02$, 1 and 6 h, respectively).

In all limbs receiving active blocks, the subjects had complete loss of cold temperature discrimination, which indicated that there were no block failures.

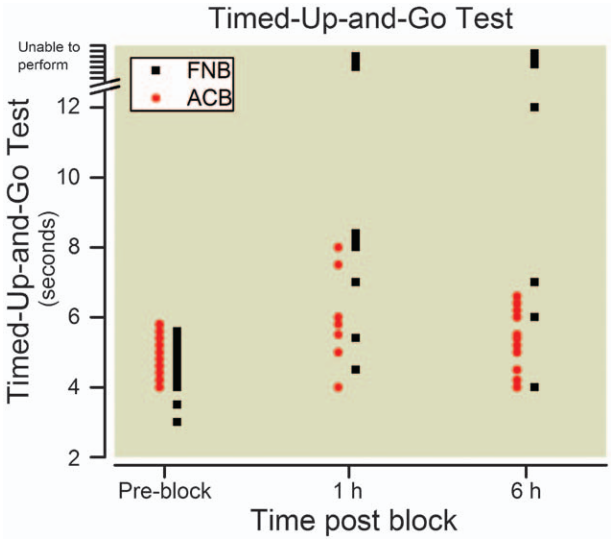

Fig. 3. Effects of the ACB and FNB on mobilization, assessed with the TUG test. Data are expressed as mean ± SD. Subjects who could not be mobilized were assigned the highest test score value obtained with each treatment and 1 s was added to this score. The subjects performed the TUG test at 1 and 6 h significantly faster after receiving an ACB compared with an FNB ($P = 0.002$ and $P = 0.008$, respectively). ACB = adductor canal block; FNB = femoral nerve block; TUG = Timed-Up-and-Go.

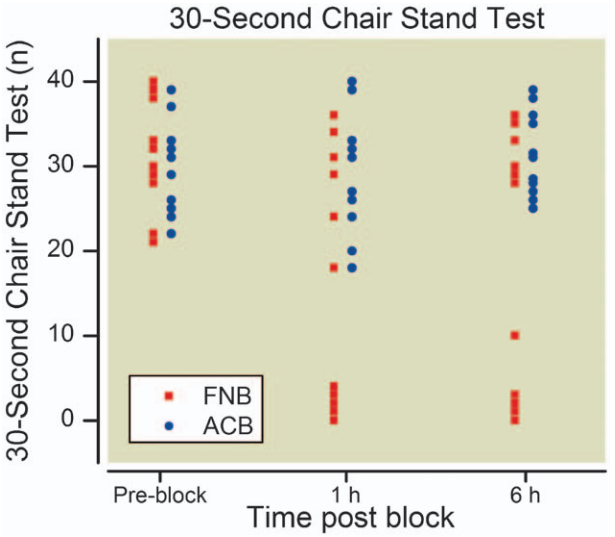

Fig. 5. Effects of the ACB and FNB on mobilization, assessed with the 30-s Chair Stand test. Data are expressed as mean ± SD. Subjects who could not be mobilized were assigned a value of 0 for the test. The number of times the subject was able to rise and sit during the 30-s Chair Stand test at 1 and 6 h was significantly reduced after the FNB compared with the ACB ($P = 0.007$ and $P = 0.02$, respectively). ACB = adductor canal block; FNB = femoral nerve block.

Table 2. Mobilization Tests

	Timed-Up-and-Go Test (s)	10-m Walk Test (s)	30-s Chair Stand Test (No. of Rises)
Preblock			
ACB	4.6 ± 0.5	4.7 ± 0.8	30.0 ± 5.4
FNB	4.2 ± 0.7	4.9 ± 0.8	30.8 ± 6.3
1 h postblock			
ACB	5.8 ± 1.1	5.8 ± 1.0	28.5 ± 6.9
FNB	9.6 ± 3.4	10.5 ± 4.2	15.6 ± 15.7
6 h postblock			
ACB	5.2 ± 0.8	5.3 ± 0.9	30.8 ± 5.1
FNB	10.3 ± 3.5	10.6 ± 4.1	18.3 ± 16.0
24 h postblock			
ACB	4.3 ± 0.9	4.9 ± 0.9	32.5 ± 5.8
FNB	4.6 ± 0.9	4.7 ± 0.5	33.8 ± 5.5

Values are reported as mean ± SD.
ACB = adductor canal block; FNB = femoral nerve block.

Discussion

The most important finding of this study was that the ACB only reduced the quadriceps muscle strength by 8% compared with baseline. Such reduction may not be functionally important in patients, as a side-to-side difference of 10% in healthy individuals is a normal variance.[23,24] In comparison, the FNB reduced the quadriceps strength by 49% compared to baseline. Furthermore, the ACB preserved the ability to ambulate better than the FNB.

There was no difference in adductor muscle strength between limbs receiving ACB and placebo ($P = 0.29$). The ACB theoretically blocks the articular branch from the posterior branch of the obturator nerve, as it enters the distal part of the adductor canal.[25] The literature does not report whether the motor fibers to the adductor magnus muscle are retained or given off before the posterior branch enters the canal.

Previous studies have shown that the obturator nerve is almost always spared when performing an FNB.[26] However, the femoral nerve supplies the pectineus muscle,[8] which is a part of the adductor muscles. The 10% reduction from baseline in the adductor muscle strength after the FNB and the statistically significant difference compared with placebo ($P = 0.007$) are probably caused by weakness of the pectineus muscle. However, this reduction may not lead to functional importance.[23,24]

The 49% reduction in quadriceps strength after the FNB, as found in our study, is less than what is reported by Charous *et al.*[1] They recently made a study in healthy volunteers comparing the effect of FNB with basal infusion *versus* repeated hourly bolus doses on quadriceps muscle strength. They used the same concentration of ropivacaine (0.1%) and the same total volume as we did (30 ml, although infused over 6 h *via* a perineural catheter), but they found a reduction of more than 80% with either method. However, Charous *et al.*[1] excluded 4 of 15 subjects as nonresponders in their primary analyses, because they had less than 20% change from baseline in quadriceps strength or no sensory effect of the FNB. In our study, 3 of 11 subjects had no or limited effect of the FNB on quadriceps muscle strength. Because we were blinded to what block the subjects received, we could not exclude patients with an insufficient motor blockade after FNB. If we had used the same exclusion criterion as Charous *et al.*,[1] the quadriceps muscle strength would have been reduced with 69%, which is closer to the result of their study. We did, however, assess for sensory loss of cold in the saphenous area at 6-h postblock, and using this criterion we had neither ACB nor FNB failures.

The comparisons of three different treatments may be considered a limitation to the study. However, the primary endpoint was clearly defined and registered** before inclusion into the study. It should be noted that no attempts have been made to adjust the secondary comparisons for multiplicity, but exact *P* values are reported so that the reader can perform post hoc adjustments.

Surprisingly, 3 of 11 subjects had a reduction in quadriceps strength after receiving ACB. This lasted for approximately 3 h, had a delayed onset, and with full motor strength regained in all subjects at 24-h postblock. Whether this is a result of a block of the nerve to the vastus medialis or a result of diffusion from the adductor canal to other branches of the femoral nerve, or alternatively diffusion to the neighboring muscles, is uncertain. Because the nerve to the vastus medialis traverses the adductor canal, we would expect this nerve to be blocked in all subjects, and would not expect a delayed and transient response. A previous study of the ACB with magnetic resonance imaging[7] showed that 30 ml injected through a catheter fills out the entire adductor canal. It is possible that this large volume can result in diffusion to the motor fibers of the femoral nerve outside of the adductor canal. This could explain the delayed and transient response seen with the ACB in this study. Future studies are needed to investigate how much volume sufficiently fills the adductor canal, and whether the reduction in quadriceps muscle strength observed in this study could be avoided with a smaller volume, without compromising the effect on pain.

In conclusion, the ACB reduced quadriceps muscle strength compared with placebo. However, the ACB only reduced quadriceps strength by 8% compared with baseline and such reduction is not considered functionally important in patients. In comparison, the FNB reduced quadriceps strength by 49% compared with baseline.

None of the blocks reduced adductor muscle strength to a degree of functional importance. Importantly, all subjects could be mobilized with an ACB, and the ability to ambulate was better preserved with an ACB compared with an FNB. This study confirms that the ACB is mainly a sensory

block, which may be a useful analgesic adjuvant for acute pain management after knee surgery. However, the block will only be of use if it provides adequate/equivalent analgesia to FNB after major knee surgery and consequently, future studies are needed to compare the analgesic effect of the ACB with the FNB in a clinical setting.

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