

The Effects of Ultrasound-Guided Adductor Canal Block Versus Femoral Nerve Block on Quadriceps Strength and Fall Risk

A Blinded, Randomized Trial of Volunteers

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Background and Objectives: Adductor canal block (ACB) has been suggested as an analgesic alternative to femoral nerve block (FNB) for procedures on the knee, but its effect on quadriceps motor function is unclear. We performed a randomized, blinded study to compare quadriceps strength following adductor canal versus FNB in volunteers. Our hypothesis was that quadriceps strength would be preserved following ACB, but not FNB. Secondary outcomes included relative preservation of hip adduction and degree of balance impairment.

Methods: The ACB was performed in one leg and the FNB in the contralateral leg in 16 volunteers using a randomized block sequence. For all blocks, 15 mL of 3% chloroprocaine was injected under ultrasonographic guidance. Maximal voluntary isometric contraction of knee extension and hip adduction was measured at baseline and at 30 and 60 minutes after block. After 60-minute assessments were complete, the second block was placed. A test of balance (Berg Balance Scale) was performed 30 minutes after the first block only.

Results: Quadriceps strength and balance scores were similar to baseline following ACB. Following FNB, there was a significant reduction in quadriceps strength ($95.1\% \pm 17.1\%$ vs $11.1\% \pm 14.0\%$; $P < 0.0001$) and balance scores (56 ± 0 vs 37 ± 17.2 ; $P = 0.02$) compared with baseline. There was no difference in hip adductor strength ($97.0\% \pm 10.8\%$ vs $91.8\% \pm 9.6\%$; $P = 0.17$).

Conclusions: Compared with FNB, ACB results in significant quadriceps motor sparing and significantly preserved balance.

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Femoral nerve block (FNB) is commonly used for analgesia in patients undergoing knee or ankle surgery.¹ However, FNB causes weakness of the quadriceps muscles that can impair effective rehabilitation and may contribute to patient falls.² Anatomical studies have determined that the majority of the motor

branches to the quadriceps muscle divide from the femoral nerve by about 5 cm below the inguinal ligament.³ The remaining motor branches, which supply the vastus medialis, continue distally along with the saphenous nerve down the thigh in the adductor canal, a fascial plane that is superficial to the femoral artery and deep to the sartorius muscle.⁴

The adductor canal block (ACB) is a technique that was first described by van der Wal⁵ as a highly successful approach to the saphenous nerve and was initially performed at the level of the distal thigh, distal to the quadriceps motor branches. This block is frequently used for anesthesia and analgesia of the medial calf and ankle.⁶ Recent case reports and a randomized trial have demonstrated superior analgesia after total knee arthroplasty (TKA) in patients receiving ACB compared with parenteral opioids.^{7–9}

Our objective was to determine if an ultrasound-guided ACB can preserve quadriceps strength, thus minimizing weakness of knee extension compared with ultrasound-guided FNB. Our primary outcome was the percentage of maximum voluntary isometric contraction (MVIC) of knee extension preserved at 30 minutes after either an ACB or FNB. Secondary outcomes included MVIC of knee extension at 60 minutes, hip adduction at 30 and 60 minutes, and assessment of fall risk with the Berg Balance Scale (BBS) at 30 minutes.

METHODS

After approval by the institutional review board at St Luke's–Roosevelt Hospital Center, 16 healthy, American Society of Anesthesiologists physical status I and II, English-speaking volunteers were recruited. Exclusion criteria included body mass index of greater than 30 kg/m^2 , history of allergy to local anesthetics, preexisting gait disturbances, and any motor or sensory deficits. Also excluded were medical students or individuals with significant background in anatomy or medicine. After written informed consent, volunteers were randomized as to which leg would receive a peripheral nerve block (PNB) first (left or right) and which of the PNBs would be done first (ACB or FNB). Volunteers received an injection on both the right and left sides during the course of the study: an ACB on one side and an FNB on the opposite side. Randomization was determined by computer-generated random sequences that were constructed and placed in sealed envelopes by a blinded research assistant (Fig. 1).

Baseline sensory, motor, and balance assessments were completed (see full description below). Standard monitors were applied (noninvasive blood pressure, electrocardiogram, SpO_2), and an intravenous cannula with a saline lock was placed following the baseline assessments. Blocks were then performed as described below.

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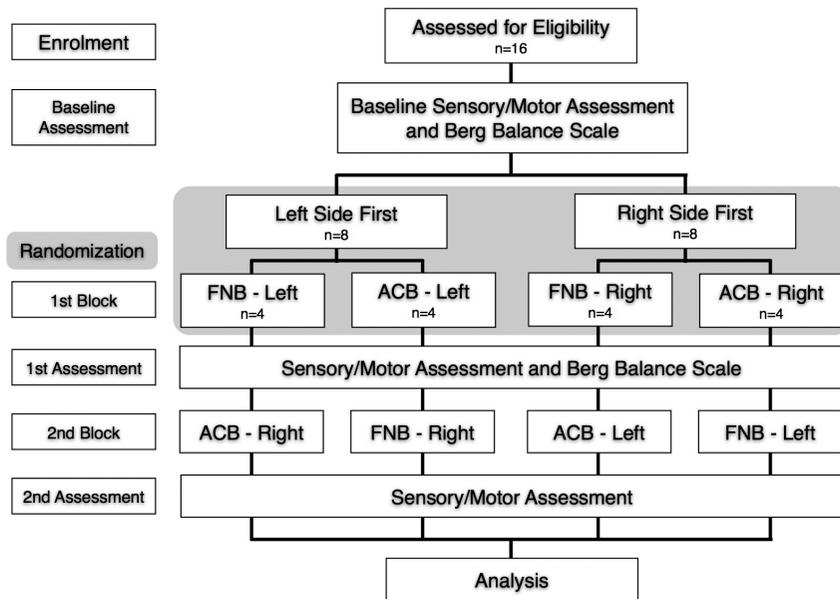


FIGURE 1. CONSORT (Consolidated Standards of Reporting Trials) diagram.

Ultrasound-Guided Femoral Nerve Block

The volunteers were placed in a supine position. An 18–6–MHz linear ultrasound transducer (Flex Focus 400 Anesthesia; BK Medical, Peabody, Massachusetts) was applied to the skin at the level of the inguinal crease. The femoral artery, fascia iliaca, and femoral nerve were visualized (Fig. 2). The skin was infiltrated with 1% lidocaine. A 22-gauge, 50-mm, short-bevel stimulating needle (Stimuplex; B Braun, Bethlehem, Pennsylvania) was inserted under ultrasound guidance using an in-plane technique from lateral to medial until a quadriceps motor response was elicited at a current between 0.5 and 0.2 mA with a pulse width of 0.1 millisecond. When necessary, small aliquots of 5% dextrose in water (D5W) were used for hydrolocalization of the needle tip. After negative aspiration, 15 mL of 3% chloroprocaine was deposited adjacent to the femoral nerve and deep to the fascia iliaca, with intermittent aspiration and in-line pressure monitoring to

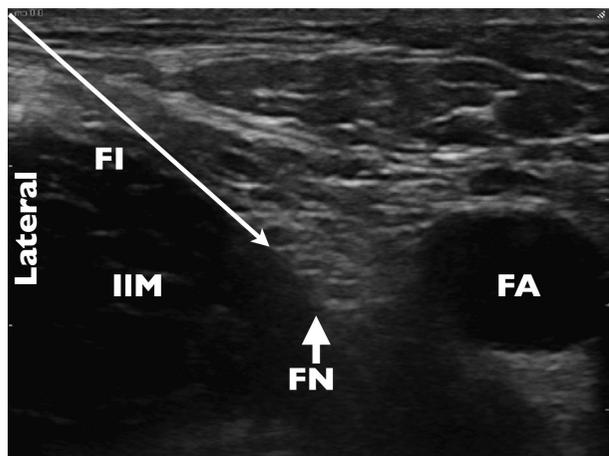


FIGURE 2. Ultrasound image obtained when high-frequency linear probe was placed in transverse view at the level of the inguinal crease. Arrow points to the injection site. FA indicates femoral artery; FN, femoral Nerve; FI, fascia Iliaca; IIM, iliacus muscle.

ensure an injection pressure of less than 15 psi (BSmart; Concert Medical, LLC, Norwell, Massachusetts). After completion of the procedure, a sterile dressing was placed over the needle insertion site. In addition, the site on the ipsilateral leg corresponding to the position where an ACB would have been completed was wiped with povidone, and a sterile dressing was placed to blind the assessors.

Ultrasound-Guided Adductor Canal Block

All blocks were done in a manner similar to a technique previously described by Kirkpatrick and colleagues.¹⁰ Volunteers were placed in a supine position with the extremity to be blocked slightly externally rotated. On the medial thigh, at the midpoint between the inguinal crease and the medial condyle, an 18–6–MHz linear ultrasound transducer (Flex Focus 400 Anesthesia; BK Medical) was placed in a transverse orientation to visualize the femoral artery in short axis deep to the sartorius muscle. The skin was infiltrated with 1% lidocaine. A 21-gauge, 100-mm, short-bevel needle (Stimuplex; B Braun) was inserted under ultrasound guidance in an out-of-plane technique to position the needle tip anterolateral to the artery and just deep to the posterior fascia of the sartorius muscle (Fig. 3). When necessary, small aliquots of D5W were used for hydrolocalization of the needle tip. Once in position, 15 mL of 3% chloroprocaine was deposited adjacent to the femoral artery and deep to the sartorius muscle, with intermittent aspiration and in-line pressure monitoring to ensure an injection pressure of less than 15 psi (BSmart; Concert Medical, LLC). After completion of the procedure, a sterile dressing was placed over the needle insertion site. The site on the ipsilateral leg corresponding to the position where an FNB would have been completed was wiped with povidone, and a sterile dressing was placed to blind the assessors.

Assessments

Block assessments were carried out at baseline and after each block. The assessor was not involved in the block procedure and was blinded to the type of block performed. The second block was placed after the 60-minute assessments of the first leg were completed.

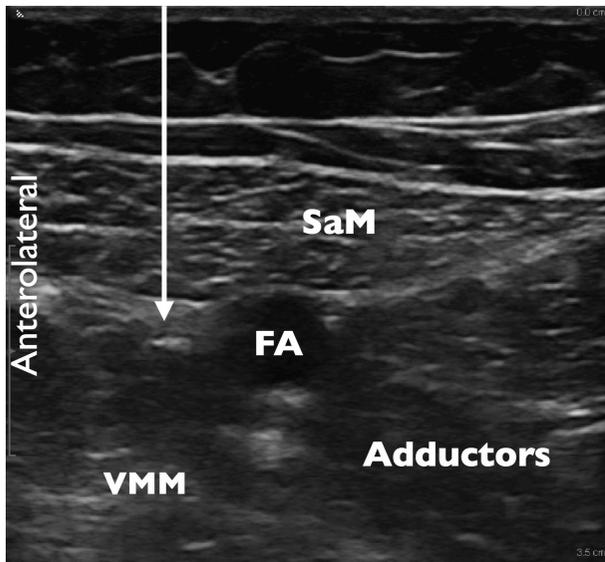


FIGURE 3. Ultrasound image obtained when high-frequency linear probe was placed in transverse view at appropriate level on patient thigh. Arrow points to the injection site. SaM, sartorius muscle; FA, femoral artery; VMM, vastus medialis muscle.

Femoral nerve block was considered successful if there was greater than 50% loss in MVIC of knee extension at 30 minutes after block. Adductor canal block was considered successful if the patient reported decreased or absent sensation at the medial midcalf to a pinprick stimulus using a 3-point scale (2 = normal sensation, 1 = decreased sensation, 0 = no sensation) at 30 minutes after block. Sensation at the medial midcalf was also tested in the femoral block leg for comparison.

Motor and balance assessments were carried out as follows:

Motor Assessments

Maximal voluntary isometric contraction of knee extension was assessed with an electronic dynamometer (MicroFET2; Hoogan Industries, West Jordan, Utah) using a protocol previously described.¹¹ With the volunteer in a seated position with the thigh parallel to the floor and leg perpendicular to the floor, the dynamometer was placed on the distal anterior tibia. Volunteers were asked to increase the force over 2 seconds up to a maximal force, while the assessor exerted an equivalent isometric force. The volunteers were asked to maintain that maximal force for 3 seconds, and the maximal force over that period was recorded. Each measurement was taken 3 times sequentially, and the mean determined. By measuring a baseline, we were able to calculate the percentage of force decreased. Baseline measurements (before PNB) were taken and compared with assessments at 30 and 60 minutes after PNB to calculate a percentage of force preserved relative to baseline.

Maximum voluntary isometric contraction of hip adduction was recorded in a similar method to the knee extension. With the volunteer in the supine position, and with the hip slightly abducted, the dynamometer was placed on the medial condyle of the ipsilateral knee being assessed. Baseline measurements (before PNB) were taken, and subsequent measurements were taken at 30 and 60 minutes after PNB. As previously, each measurement was taken 3 times, and their mean calculated. Strength of hip adduction was again recorded as a percentage of force relative to the baseline. Baseline measurements (before PNB)

were compared with assessments at 30 and 60 minutes after the nerve block to determine a percentage of force preserved.

Fall-Risk Assessments

Volunteers were assessed for risk for falls using the BBS, which is a psychomotor test that involves a series of 14 standardized instructions; volunteers are graded on a 0- to 4-point scale specific to each task.¹² The maximum possible score is 56. In elderly patients, a BBS score of less than 45 indicates at least a moderate risk for falls.¹³

This test was conducted at baseline (preblock) and at 30 minutes after placement of the first block, with assisted support if needed following the block. The BBS assessment was performed only once per patient, following the first block. Thus, half of the volunteers completed BBS assessments after FNB, and the other half of the volunteers completed it after ACB.

The power analysis was based on a study by Bohannon¹¹ in which mean isometric force and standard deviation for the quadriceps muscle were calculated (154.95 ± 94.89 N). We expected that the FNB would result in a substantial transient quadriceps weakness. We felt that a 50% difference in quadriceps strength between groups would be clinically important. At $\alpha = 0.05$ and power = 0.80, we estimated a sample size of 14 volunteers (28 nerve blocks). We recruited 16 volunteers in the event of unilateral blocks that would eliminate the volunteer from the paired analyses. This also allowed us to have an even number of each type of block per side.

The statistical analysis was performed using SAS version 9.1.3 (SAS Institute, Cary, North Carolina). Continuous data are reported as mean \pm SD. Paired samples were compared using the paired *t* test; $P < 0.05$ was considered significant.

RESULTS

Sixteen healthy volunteers completed this study. Average age was 29 years (range, 18–62 years), and average body mass index was 24.4 kg/m^2 (range, $18.5\text{--}28.4 \text{ kg/m}^2$). Initial sensory and motor examinations and BBS assessments were normal.

All blocks had good-quality ultrasound images, and appropriate spread of local anesthetic was visualized. No block required more than 2 mL of D5W for hydrolocation. All FNBs demonstrated a motor response to nerve stimulation between 0.5 and 0.2 mA at a pulse width of 0.1 millisecond, as well as substantial quadriceps weakness (>50% loss). All blocks (ACBs and FNBs) demonstrated decreased or absent sensation at the medial calf.

Maximum voluntary isometric contraction of knee extension was preserved with ACB compared with FNB at 30 minutes ($95.1\% \pm 17.1\%$ vs $11.1\% \pm 14.0\%$, respectively; $P < 0.0001$) and at 60 minutes ($98.8\% \pm 15.5\%$ vs $41.2\% \pm 34.3\%$, respectively; $P < 0.0001$). There was no difference in MVIC during hip adduction at 30 minutes ($97.0\% \pm 10.8\%$ vs $91.8\% \pm .6\%$; $P = 0.17$) or at 60 minutes ($96.3\% \pm 15.4\%$ vs $93.6\% \pm 8.8\%$; $P = 0.62$) (Fig. 4).

There was no impairment of the BBS in volunteers who received an ACB, whereas it was significantly impaired in volunteers who received an FNB (56 ± 0 vs 37 ± 17.2 ; $P = 0.02$).

DISCUSSION

Our results demonstrate that ACB does not significantly affect the quadriceps motor function or balance, whereas FNB substantially decreases quadriceps motor function and increases the risk for falls as measured by the BBS.

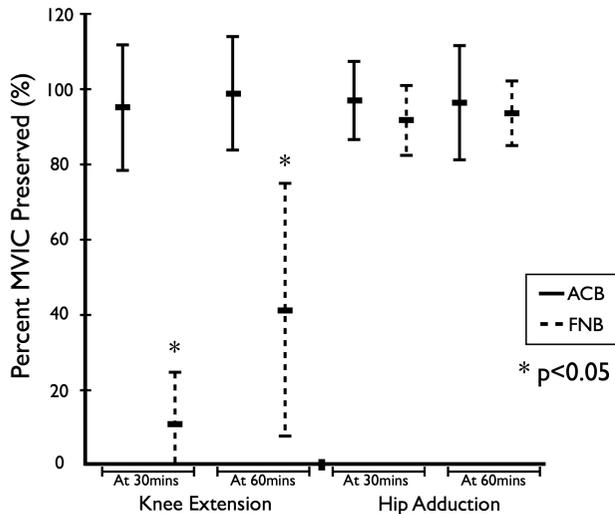


FIGURE 4. Motor assessment results.

The ACB provides cutaneous anesthesia to the medial calf and ankle and has been used successfully to reduce postoperative pain in a variety of surgical procedures, including ankle surgery¹⁴ and knee arthroscopy.¹⁵ However, controversy exists as to the optimal level on the thigh at which to perform the ACB. Whereas some clinicians advocate for a distal approach (eg, distal third of the femur),¹⁶ our clinical experience has been that an approach at midfemur does not impair motor function, a result that is reproduced in this volunteer study. In addition, a mid-femoral site may more reliably ensure a block proximal to the branching of the infrapatellar branch of the saphenous nerve, potentially leading to a more complete block of the knee.¹⁷ The articular branches of the obturator nerve provide variable sensation to the posteromedial aspect of the knee and traverse the adductor canal before innervating the joint.⁸ Local anesthetics deposited in the adductor canal may provide improved analgesia by blocking these perigenicular obturator fibers in addition to the femoral articular branches.⁹ However, our findings suggest that significant blockade of obturator motor fibers (as measured by strength of hip adduction) does not occur when the ACB is performed under the conditions of our study.

Femoral nerve block is a standard analgesic intervention following TKA or anterior cruciate repair in many centers. However, its principal disadvantage is the resulting motor weakness that may contribute to impaired ambulation and rehabilitation, as well as elevated fall risk. An increased trend toward fast-tracked rehabilitation programs after TKA has resulted in an expectation of many patients ambulating on the day of surgery.¹⁸ Recent studies have suggested that ACB provides significant analgesia to the knee following arthroplasty.^{7,9}

Block-related falls can occur from a variety of sources, including sensory loss, motor weakness, impaired proprioception, or a combination of these.² As there is no standard for assessing fall risk after PNBs, we chose a validated fall-risk assessment tool, the BBS. The BBS, a well-known balance measurement tool,¹⁹ was initially designed and validated in elderly patients to predict falls¹² but has since been used in other cohorts with neuromuscular disease, such as patients with stroke, multiple sclerosis, and Parkinson disease. The test not only evaluates balance in positions of increasing difficulty by decreasing the base of support, but also tests transfers and retrieving objects from the floor.¹⁹ The BBS scores for the ACB group were identical

to baseline, whereas every subject in the FNB group demonstrated impaired balance.

There were some potential limitations to our study. First, we used the BBS to assess balance and fall risk. Although the BBS has not been validated in our patient population, it has been validated in patients with neuromuscular disease; as such, it may also be useful in the assessment of the induced neuromuscular dysfunction of a PNB. Second, because our subjects did not undergo surgery, no conclusions regarding the efficacy of our blocks for surgical anesthesia can be made. We chose to do the study in volunteers to reliably assess motor strength without the potential confounders of pain, swelling, muscle spasm, or bandages present following knee surgery.^{5,20-24} Although it is difficult to assess analgesic efficacy in this model, it is ideal for the assessment of motor sparing and balance, and previous studies have assessed the analgesic efficacy of both ACBs^{8,9} and FNBs.^{1,14} We used a reduction in quadriceps strength as confirmation of successful FNB as it is the most objective assessment tool and used sensory block for ACB as there is not an equivalent motor end point at this level. Chloroprocaine was used because of its relatively short latency and duration of action. This ensured that volunteers could have both blocks resolve within a total of approximately 5 hours and be safely discharged home the same day. We chose 30 minutes for our primary end point assessments, as the blocks would be at their peak pharmacodynamic effect. Finally, the use of dilute local anesthetics when performing FNBs (ie, ropivacaine $\leq 0.2\%$) may or may not have reduced quadriceps weakness relative to higher-concentration local anesthetics such as the one used in this study. However, even very dilute solutions of ropivacaine (0.1%) have been shown to have a substantial effect on quadriceps weakness during FNB.²⁵ It is for this reason that an anatomical (rather than pharmacologic) approach may represent an encouraging solution to this clinical problem.

In summary, our study demonstrates that ultrasound-guided ACB spares motor function and balance compared with FNB. Randomized controlled trials comparing ACB to FNB in surgical populations are indicated to determine the analgesic effects of ACB for specific procedures.

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