Adductor Canal Block With 10 mL Versus 30 mL Local Anesthetics and Quadriceps Strength

A Paired, Blinded, Randomized Study in Healthy Volunteers

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Background and Objectives: Adductor canal block (ACB) is predominantly a sensory nerve block, but excess volume may spread to the femoral triangle and reduce quadriceps strength. We hypothesized that reducing the local anesthetic volume from 30 to 10 mL may lead to fewer subjects with quadriceps weakness.

Methods: We performed a paired, blinded, randomized trial including healthy men. All subjects received bilateral ACBs with ropivacaine 0.1%; 10 mL in 1 leg and 30 mL in the other leg. The primary outcome was the difference in number of subjects with quadriceps strength reduced by more than 25% from baseline in 2 consecutive assessments. Secondary outcomes were quadriceps strength as a percentage of baseline at predefined time points, functional outcome assessed by the 30-Second Chair Stand Test (1 leg at a time), and sensory block. Clinicaltrials.gov Identifier: NCT01981746.

Results: We included and analyzed 26 subjects. For either volume, 2 subjects had a reduction in quadriceps strength by more than 25% from baseline (difference, 0%; 95% confidence interval, −13 to 13; $P > 0.999$). Similarly, we found no significant differences between volumes in quadriceps strength at any of the predefined time points or in sensory block. The only statistically significant difference between volumes was found in the 30-Second Chair Stand Test at 2 hours ($P = 0.02$), but this difference had disappeared at 4 hours ($P = 0.06$).

Conclusions: Varying the volume of ropivacaine 0.1% used for ACB between 10 and 30 mL did not have a statistically significant or clinically relevant impact on quadriceps strength.

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Quadriceps weakness is pronounced after total knee arthroplasty because of the surgical procedure itself. The reason for impaired muscle function is not fully understood, but pain, swelling, and reflex inhibition are all potential factors.[1] Early rehabilitation may prevent this impairment.[2]

Although peripheral nerve blocks help control postoperative pain after total knee arthroplasty, concurrent muscle weakness may hinder mobilization and delay physical therapy. In contrast, the adductor canal block (ACB), a novel block used for pain treatment after knee surgery, preserves muscle strength and has the potential to facilitate early rehabilitation.[3–8]

Injection of a relatively large volume of local anesthetics into the adductor canal will, in theory, anesthetize the nerves running through the canal: the saphenous nerve, the nerve to the vastus medialis, and the posterior branch of the obturator nerve.[9,10] All of these nerves send sensory contributions to the knee. However, the adductor canal runs in continuation of the femoral triangle, and a large volume injected into the canal may spread to the femoral triangle. In a previous study, we showed that an ACB with 30 mL ropivacaine 0.1% reduced quadriceps femoris strength by a mean value of 8% from baseline.[3] Although a side-to-side difference of 10% is normal in healthy individuals, this is not considered to be clinically relevant.[11,12] However, in 3 subjects, strength was reduced by more than 25% from baseline,[3] which is considered a real change in knee extension strength.[13,14] This excessive muscle affection may represent block of the nerve to the vastus medialis. Alternatively, it may have been the result of spread to neighboring muscles or to the femoral triangle, which might have been avoided if we had injected a smaller volume.

The aim of the present study was to investigate the effect of 2 different volumes of ropivacaine 0.1% on muscle strength after ACB in healthy volunteers. We hypothesized that a volume of 10 mL would result in fewer subjects with reduced quadriceps strength (>25% from baseline) than a volume of 30 mL (primary outcome). Secondary outcomes were quadriceps strength as a percentage of baseline at predefined time points, functional outcome assessed by a modified 30-Second Chair Stand Test, and pain response to tonic heat stimulation.

METHODS

This randomized, blinded, controlled, crossover study was conducted at Rigshospitalet, University of Copenhagen, Copenhagen, Denmark. Before enrollment, approval was obtained from the Ethics Committee of the Capital Region of Denmark (H-3-2013-135), the Danish Medicines Agency (2013-003522-83), and the Danish Data Protection Agency. The study was prospectively registered at clinicaltrials.gov (NCT01981746). Copenhagen University Hospital GCP (Good Clinical Practice) Unit monitored the study.

After obtaining written informed consent, we enrolled men aged 18 to 30 years with a body mass index of 18 to 25 and an American Society of Anesthesiologists status of I into the study. The enrollment period ran from November to December 2013. Exclusion criteria were diabetes mellitus, intake of opioids or steroids within the last 4 weeks (except oral inhalation), any drug intake within the last 48 hours, any pathology, former trauma or

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P.J. has received speaker's honoraria from Smiths Medical USA, and Z.J.K.N. occasionally receives speaker's honoraria from B. Braun Medical, Melsungen, Germany. The other authors declare no conflict of interest.

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surgery to the leg, inability to cooperate, non-Danish speakers, alcohol or drug abuse, or history of allergy to local anesthetics. Subjects were instructed not to indulge in rigorous exercise for 24 hours before the study day.

Interventions

The ACB was performed under ultrasound (US) guidance (Venue 40; GE Medical Systems, Wuxi, China), as described previously.[3] A linear 12 L probe was placed in a transverse orientation at the midthigh level, approximately halfway between the patella and the anterosuperior iliac spine. After skin preparation with chlorhexidine gluconate and isopropyl alcohol, we introduced a 22-gauge 80-mm-long insulated needle (Ultraplex; B. Braun Medical, Melsungen, Germany) in plane and lateral to the US probe. We identified the femoral vessels underneath the sartorius muscle and injected ropivacaine 0.1% (10 or 30 mL) in proximity of the saphenous nerve, usually found anterolateral to the femoral artery (Fig. 1). Ropivacaine was injected incrementally after negative aspiration to minimize the risk of intravascular injection.

All subjects received 2 ACBs with ropivacaine 0.1%, one in each leg, but with different volumes according to randomization: 10 mL in 1 leg and 30 mL in the other. The first block was always placed in the right leg and the second block in the left leg. We diluted ropivacaine 0.2% by adding isotonic saline in a 1:1 ratio, and the total dose (10 or 30 mL ropivacaine 0.1%) was equally divided into 2 syringes. All blocks were performed by one of 2 anesthesiologists (Z.J.K.N. or D.L.I.), both experienced in US-guided peripheral nerve blocks. Designated residents assisted block performance and verified injection of the correct volume.

Randomization And Blinding

One of the investigators (M.L.F.) prepared a computer-generated randomization list at randomization.com in a 1:1 ratio and in blocks of 10. Subjects were assigned consecutive numbers on inclusion to the study and received the treatment corresponding to the randomization list.

The anesthesiologist performing the block and his assistants could not be blinded to volume, but blinding of outcome assessors and participants was ensured. During block performance, subjects' view of the injection site was carefully blocked by drapes. Only the anesthetist performing the block and his assistant were present in the block room during block performance, but neither of them was involved in data collection, data handling, or any further treatment of the subjects.

Assessment Of Outcomes

Quadriceps muscle strength was assessed using a handheld dynamometer (HHD; Lafayette Instrument, Lafayette, Indiana), as described in a previous study.[3] One single investigator performed all measurements in a single subject. Muscle strength was assessed as maximum voluntary isometric contraction (MVIC) and calculated as a percentage of the preblock baseline value for each time point. A decrease by more than 25% from baseline was considered a reduction in strength because this represents a real change in knee extension strength.[13,14]

Functional outcome was assessed by a modified 30-Second Chair Stand Test as described by Jones et al,[15] measuring how many times the subject can get up from a chair and sit down again during a 30-second period. Subjects were not allowed to use their arms for support during the test. Because the subjects had bilateral ACBs with different treatments in each leg, we modified the test in such a way that subjects performed the test using only 1 leg at the time. A Timed-Up-and-Go (TUG) test was also performed, but this was performed using both legs and, therefore, for descriptive purposes only. The TUG test measures the time it takes a person to get up from a chair, walk 3 m, return, and sit down again.[16] No walking aids were allowed for the TUG test. Both tests have been validated in previous studies.[15,16]

Quantitative sensory testing was performed using a tonic heat pain response test. In this test, we assessed pain response to a tonic heat pain stimulus using a computer-based thermode system (2.5 cm^2, Thermotest; Somedic A/B, Hörby, Sweden). The probe was placed on the medial side in the middle third of the lower leg and heated to 45°C (ramp rate 5°C/s) for 30 seconds.

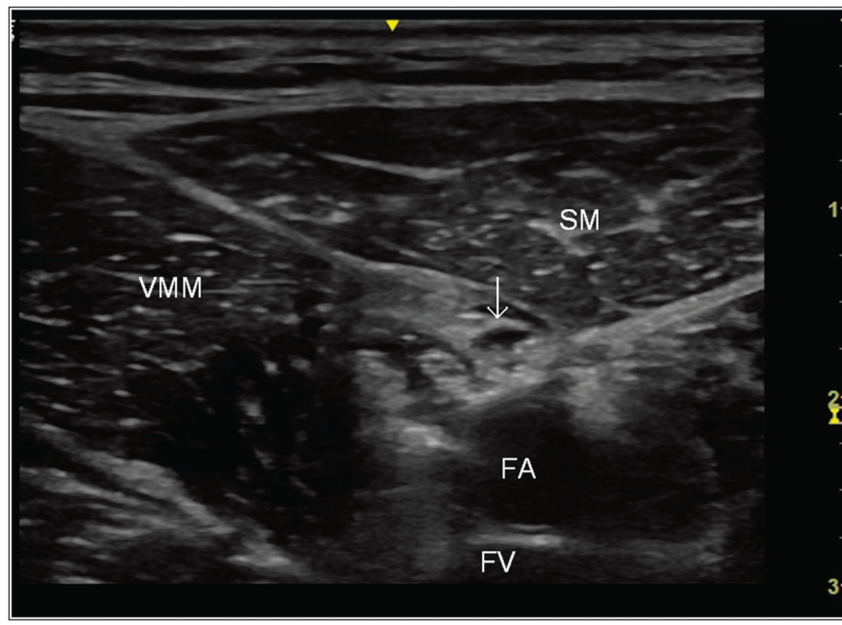

FIGURE 1. Ultrasound image after injection of local anesthetics into the adductor canal at the midthigh level. White arrow, saphenous nerve; SM, sartorius muscle; VMM, vastus medialis muscle; FA, femoral artery; FV, femoral vein.

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Subjects rated their pain on a visual analog scale (VAS, 0 mm = no pain, 100 mm = worst possible pain) during the test, and the maximum pain score during the test was noted.

All outcomes were assessed by one of 2 investigators (P.J. and K.L.H.). Muscle strength and the tonic heat pain response test were assessed before interventions (preblock), at 30 minutes postblock, and then every hour until hour 6 postblock while the modified 30-Second Chair Stand Test and the TUG test was performed preblock and at 2 and 4 hours postblock.

Finally, we assessed block success rate by testing temperature discrimination ability in the saphenous innervation area (ipsilateral thigh used for comparison) using an alcohol swab at 1 and 6 hours postblock.

Outcomes

The primary outcome was the difference between volumes in the number of subjects experiencing a reduction in quadriceps strength by 25% or more from the preblock baseline value in 2 consecutive readings (0.5–6 hours). Secondary outcomes were difference in quadriceps MVIC as a percentage of baseline at 2, 3, and 4 hours postblock and calculated as area under the curve (AUC) for the interval 0.5 to 6 hours postblock, difference in mean VAS pain scores during tonic heat stimulation (0.5–6 hours postblock), and difference in the number of sits and rises in the modified 30-Second Chair Stand Test at 2 and 4 hours.

Sample Size Calculation

Sample size calculation was calculated using the following formula for comparing proportions in a crossover trial: $n = [(z_{\alpha/2} + z_{\beta})^2\ \sigma_d^2]/[a\varepsilon^2]$.[17] Based on our previous study, we assumed an SD (σ_d) of approximately 50% and considered a 20% difference in proportions (ε) to be clinically relevant. A sample size of 24 subjects will be sufficient to detect a 20% difference in the proportion of subjects with reduced quadriceps strength, with 80% power and a 5% significance level. To compensate for dropouts, we planned for an inclusion of 26 subjects.

Statistical Analysis

Data were analyzed using SPSS version 19.0 (SPSS, Chicago, Illinois). Dichotomized data were compared using a McNemar test and Liddell exact test for paired proportions. A Kolmogorov-Smirnov test was performed to assess normality of variable distributions. Parametric data are presented as mean SD and analyzed using a 2-sample *t* test for paired data and nonparametric data as median (10–90 percentiles) analyzed using the related-samples Wilcoxon signed-rank test. At each time point, the mean value of 3 consecutive trials of MVIC was used to calculate the percentile change from baseline. Furthermore, we calculated the AUC for the percentile change in MVIC (0.5–6 hours) by adding the AUC between each pair of consecutive observations $[(t2 - t1)\ (y1 + y2)/2]$. Maximum VAS pain scores between volumes were compared by calculating the mean value for the entire period from each subject. A 2-sided value of $P < 0.05$ was considered statistically significant.

TABLE 1. Subjects' Characteristics

No. subjects	26
Age, y	24 ± 2
Height, cm	185 ± 7
Weight, kg	78 ± 8
Body mass index, kg/m^2	23 ± 2

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

TABLE 2. Quadriceps Muscle Strength in Percentage of Preblock Baseline Value

Time Postblock	MVIC in % of Baseline, Mean (SD) 10 mL	30 mL	Mean Difference	95% CI of the Difference	*P*
2 h	102 (19)	97 (26)	5 (29)	−7 to 17	0.38
3 h	108 (25)	98 (21)	10 (30)	−2 to 23	0.09
4 h	108 (27)	102 (24)	6 (29)	−6 to 17	0.32

RESULTS

We enrolled 26 subjects. All the participants completed the study and were included in the analyses. Subjects' characteristics are displayed in Table 1. One patient developed an infection in the thigh 3 days postblock, which quickly resolved during treatment with antibiotics. No other adverse or serious adverse events occurred during the study.

Varying the volume of local anesthetic had no impact on the number of subjects experiencing a reduction in quadriceps strength by more than 25% from baseline: 4 subjects in total, two with each volume (4 discordant pairs: McNemar difference, 0.0%; 95% confidence interval [95% CI], −13 to 13; $P > 0.999$; Exact test after Liddell, RR = 1.00; $P > 0.999$).

Accordingly, quadriceps strength after the 2 volumes did not differ significantly at any of the predefined time points at 2, 3, or 4 hours postblock (Table 2; Fig. 2). Neither was there a difference between treatments in the averaged weighted AUC (0.5–6 h/5.5): 106% ± 21% versus 100% ± 19%, 10 and 30 mL, respectively (mean difference 6% ± 24%; 95% CI, −3 to 16; $P = 0.20$).

The only difference between volumes was found in the modified 30-Second Chair Stand Test at 2 hours postblock. The mean decrease from the preblock value in the number of sits and rises was 3 in the 10-mL group and 6 in the 30-mL group ($P = 0.02$). This difference was no longer statistically significant at 4 hours; mean decrease −1 and −4, 10 and 30 mL, respectively ($P = 0.06$; Fig. 3).

Moreover, there was no significant difference in maximum VAS pain scores during the tonic heat pain response test: median 4 (0–25) mm versus 1 (0-28) mm, 10 and 30 mL, respectively (median difference, 2 mm; 95% CI, −2 to 6; $P = 0.27$; Fig. 4).

All subjects could be mobilized and perform the TUG test with bilateral ACBs, with minimal changes between the preblock and postblock scores: 6.3 ± 0.9 seconds preblock compared with 6.4 ± 0.9 and 6.2 ± 0.7 seconds 2 and 4 hours postblock, respectively.

Block success was assessed using an alcohol swab; at 1 hour postblock, all subjects except one (10-mL treatment) had a sensory block in both legs. At 6 hours, the ACB had resolved in 7 of 26 limbs receiving 10 mL and in 2 of 26 limbs receiving 30 mL. Both subjects with resolution in the limb receiving 30 mL also had resolution in the opposite limb receiving 10 mL, thus, 5 of the subjects with block resolution at 6 hours had resolution in only 1 leg (5 discordant pairs).

DISCUSSION

The most important finding in this study was that reducing the volume for an ACB from 30 to 10 mL of 0.1% ropivacaine

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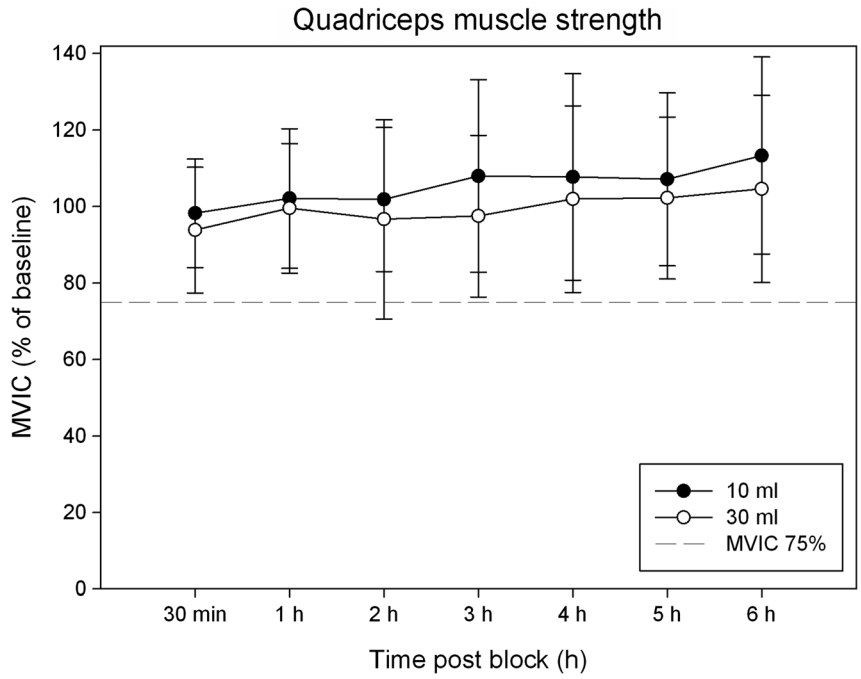

FIGURE 2. Effect of an adductor canal block with 10 mL versus 30 mL 0.1% ropivacaine on quadriceps muscle strength. Muscle strength was assessed as MVIC. There were no significant differences in quadriceps strength between the 2 volumes at any of the predefined time points: 2, 3, or 4 hours postblock ($P > 0.05$). Neither was there a difference between treatments when muscle strength was calculated as AUC (0.5–6 h/5.5): 106% ± 21% versus 100% ± 19%, 10 and 30 mL, respectively (95% CI −3 to 16; $P = 0.20$). Data are expressed as mean ± SD. The dashed line at MVIC 75% represents the clinically relevant 25% reduction in quadriceps strength.

had no significant impact on quadriceps strength. There was no difference in strength when looking at the number of subjects with quadriceps strength reduction by more than 25%. Neither was there a difference in the mean values at predefined time points nor when comparing the results for the whole period (calculated as AUC). Importantly, the difference in strength between volumes

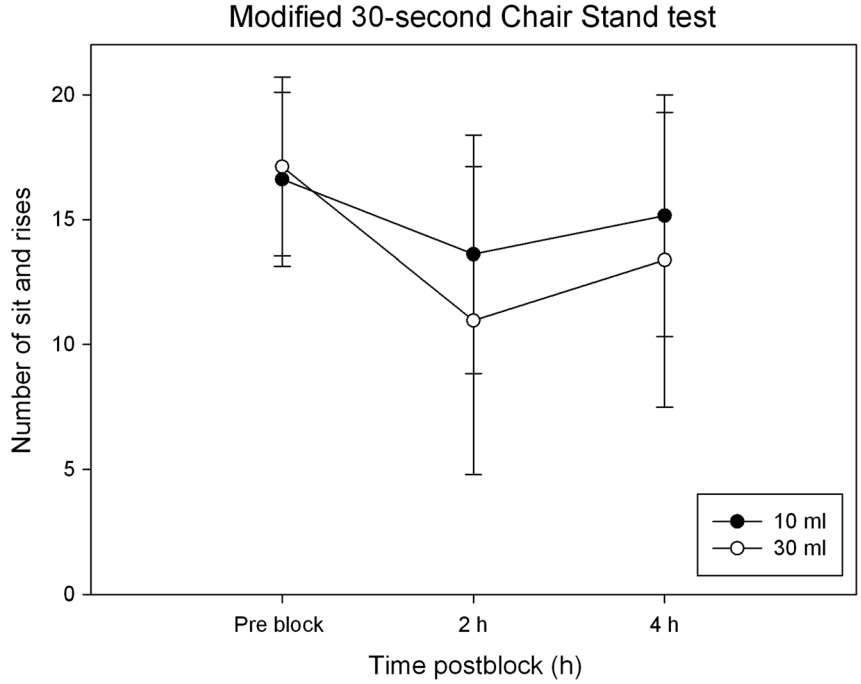

FIGURE 3. Effect of an adductor canal block with 10 mL versus 30 mL 0.1% ropivacaine on mobilization, assessed by the modified 30-Second Chair Stand Test. At 2 hours postblock, the mean decrease in the number of sits and rises from the preblock value was 3 in the 10-mL group and 6 in the 30-mL group ($P = 0.02$). At 4 hours, this difference was no longer statistically significant; mean decrease of 1 and 4, 10 and 30 mL, respectively ($P = 0.06$).

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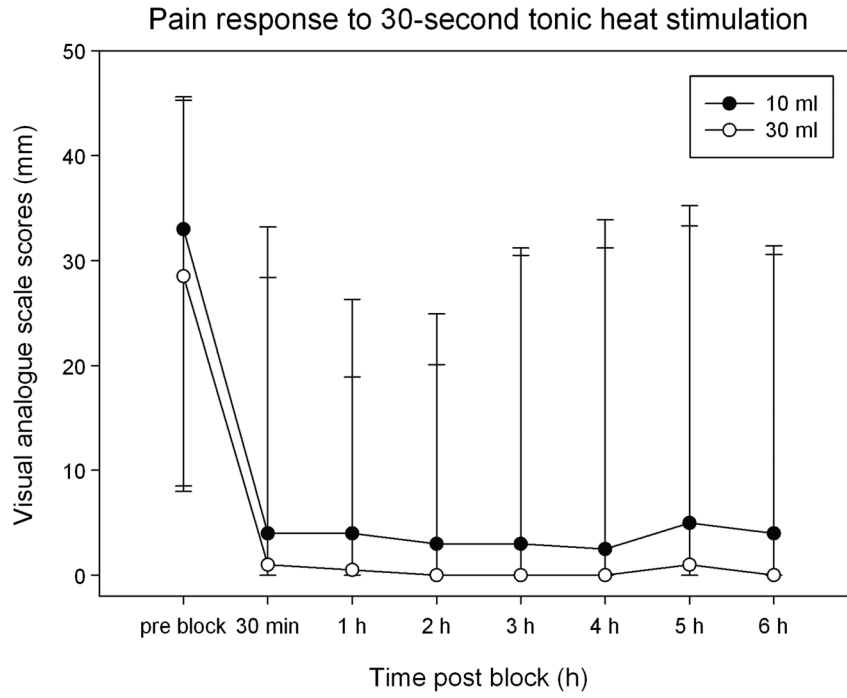

FIGURE 4. Effect of adductor canal block with 10 mL versus 30 mL 0.1% ropivacaine on maximum visual analog scale pain scores during a tonic heat pain response test. Volumes were compared by calculating the mean value for the entire period from each subject (0.5–6 hours postblock), showing no significant differences between treatments: 4 (0–25) mm versus 1 (0–28) mm, 10 and 30 mL, respectively (95% CI, −1.5 to 6; $P = 0.27$). Data are expressed as median (10–90 percentiles).

was never more than 10%, which is equal to the side-to-side difference commonly seen in healthy individuals.[11,12]

In the present study, 4 subjects had a reduction in strength by more than 25% in total, but there was no difference between volumes. Interestingly, every single subject could be mobilized without gait aids with bilateral ACBs and completed the TUG test with performance scores close to the preblock scores. Even the 4 subjects with quadriceps weakness performed the TUG test with no more than a 2-second increase in time despite a 25% to 75% decrease in strength. Thus, although a 25% decrease in knee extension strength may represent a real change, the clinical relevance of this is unknown.

The only statistically significant effect of volume was found in the modified 30-Second Chair Stand Test at 2 hours postblock. Although this test may be more sensitive in assessing muscle affection than MVIC with a handheld dynamometer, it may not be feasible in a surgical population. Many patients present with substantially reduced quadriceps function before surgery and may not even be able to perform the test using both legs (when no arm support is allowed). Of note, when both legs are used for the test, sensitivity decreases because the unaffected leg overtakes the function of the operated leg. Although the difference in the modified 30-Second Chair Stand Test was statistically significant, the clinical relevance of this is unknown. However, the unaffected performance in the TUG test indicates that any potential gain in function obtained by reducing volume will probably be modest.

It is a limitation to the study that the volume needed to fill the adductor canal is unknown. We aimed to use the lowest possible volume for our comparator to minimize the risk of overlooking any potential muscle-sparing effect by reducing the volume. The volume of the comparator was set to 10 mL based on a previous case report showing that 15 mL filled the canal in cadavers.[18] Nonetheless, even 10 mL may overfill the canal, and this may explain the lack of difference between treatments in the present study. However, if volumes smaller than 10 mL are required to avoid spread of local anesthetics beyond the adductor canal, it may have other consequences. For instance, the analgesic effect of the ACB is believed to depend on more than just the saphenous nerve and smaller volumes may not sufficiently spread to all nerves within the canal. Recently, it has also been suggested that an ACB may even involve analgesia of the sciatic nerve.[19] We found no effect of reducing volume (and total dose) on pain response to tonic heat stimulation in the present study. However, the true impact of volume for an ACB on analgesia can only be investigated in postsurgical patients. Although our study was not designed nor powered to detect differences in block duration, delivering smaller injections around nerves may affect the duration of the nerve block.

Ropivacaine 0.1% is rarely used in a clinical setting. Nonetheless, our results indicate successful block of the nerves within the adductor canal. This is reflected in the block success rate (1 failed block out of 52 blocks) and in the pain scores from the tonic heat stimulation test (Fig. 4). Contrary to this, assessing the success rate in terms of motor block is to no avail because the ACB is predominantly a sensory nerve block. Thus, it is unknown whether higher concentrations of ropivacaine may result in a higher rate of motor block, and future trials are required to investigate whether a decreased volume in such a scenario may lead to a motor-sparing effect.

In a previous trial, we found a 27% rate of quadriceps weakness.[3] However, in the current study, only 8% of subjects experienced a 25% reduction in MVIC after an ACB with 30 mL. The reason for this discrepancy in unknown, but the small sample sizes used in both studies may explain some the difference, and larger studies are needed to evaluate the true incidence of clinically relevant quadriceps affection after an ACB. Considering our secondary outcomes are closely related to the primary outcome (MVIC analyzed as continuous data instead of dichotomous data); we

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performed a post hoc power calculation for comparing quadriceps strength as a continuous variable. This showed that the present study, with an SD of approximately 30% (Table 2), has 98% power to detect a clinically relevant difference of 25% between treatments if it actually exists.

Recently, 2 case reports of decreased quadriceps strength hindering mobilization after an ACB have been published.[20,21] The present study indicates that the occasional quadriceps weakness will not be avoided by reducing volume, but the explanation to these rare events remains unknown. The 4 subjects who did show quadriceps weakness in our study only did so unilaterally, and there were no similarities between them separating them from the rest of the study population. Their height and weight were all within 1 SD of the mean height and weight of the study population, and their baseline values for quadriceps strength and in the functional tests were also about average. Other possible explanations may be anatomical differences and injection pressure. In the present study, we did not use a standardized injection pressure. This should be subject to further investigation. In the meantime, clinicians should be aware that quadriceps weakness can occur after an ACB, and routine assessment of quadriceps strength before attempting to mobilize patients is advocated.

In conclusion, the present study found that reducing the volume for an ACB from 30 to 10 mL of 0.1% ropivacaine did not have a significant impact on quadriceps muscle strength. There was a small difference in functional outcome assessed by the modified 30-Second Chair Stand Test. However, the mean differences in strength did not exceed the side-to-side difference commonly seen in healthy individuals and the postblock performance in the TUG test was nearly identical to the preblock performance. Thus, any potential gain in function obtained by reducing the volume will probably be modest at the most. In addition to investigating what volume sufficiently fills the adductor canal, future studies should also focus on the volume's effect on analgesia and block duration in a surgical setting.

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