Adductor Canal Blocks: An Observational Ultrasound Study in Volunteers to Identify the Relationship of the True Adductor Canal to Commonly Described Block Approaches and a Review of the Literature

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Research article

Keywords: Adductor canal block; Ultrasound Anatomy

Posted Date: July 26th, 2019

DOI: https://doi.org/10.21203/rs.2.11977/v1

Abstract

Background There is controversy over the site at which the ultrasound-guided adductor canal blocks (ACB) should be performed, and the anatomic relationship of these sites to the true adductor canal (AC). Most studies describe performing the ACB at the anatomical mid-point of the thigh (mid-thigh ACB, mtACB), or 2-3 cm above the inferior border of AC (distal ACB, dACB). The aim of the study was to determine the relationship of these approaches to the true anatomical AC in volunteers. Methods Using ultrasonography and surface landmarks, we characterized the AC anatomy of both lower limbs in 60 adult volunteers (30 males, 30 females). The primary outcome variable was the distance from the mid-thigh approach to the superior border of AC. Calculated secondary measurements were the distance between the 2 approaches and the length of AC. Results The (median [IQR]) needle entry point for mtACB was above the superior border of the AC in both males (5.5 cm [4.6-7.0]) and females (6.6 cm [5.8-7.3]) (P = 0.045 [95% CI of the difference in medians, -1.63 to 0.00 cm]). The median distance between the needle entry points of mtACB and dACB in males vs females were not different (median difference: 0.63 cm; 95% CI, -0.25 to 1.50). The length of the adductor canal was 1.5 cm longer in males compared to females (95% CI, 1.00 to 2.25 cm) Conclusions AC blocks performed at mid-thigh or more proximal are outside the anatomical adductor canal. A review of recent literature shows 3 different sites where AC blocks are performed; the majority of the blocks are performed in the mid-thigh region and hence outside of the true adductor canal.

Background

The adductor canal block (ACB) has replaced the femoral nerve block as the regional anesthetic technique of choice for knee surgery, because it preserves quadriceps function while providing comparable analgesia.[1-4] For foot and ankle surgery, the adductor canal (AC) approach to saphenous nerve block has been shown to be superior to a distal approach.[5] When performed for knee surgery, the ideal ACB should achieve maximal analgesia, minimal weakness and should be suitable for nerve catheter placement, if desired. In order to achieve these goals, AC blocks have been performed at various sites underneath the sartorius muscle, ranging from a proximal needle entry point at the site the medial border of the sartorius first covers the superficial femoral artery (SFA) to a more distal point just proximal to the adductor hiatus. Although all these entry points are “subsartorial,” it is unclear whether they lie within the boundaries of the true “anatomical adductor canal.” Furthermore, controversy regarding the boundaries of the adductor canal, and the alternate term, “subsartorial canal,” adds to the confusion.[6-9] Most previous studies describe performing the ACB at one of two locations: a) the anatomical mid-point between the anterior superior iliac spine and base of patella, referred to here as the *mid-thigh adductor canal block* (mtACB),[10] or b) 2-3 cm above the inferior border of AC or the adductor hiatus, referred to as the *distal adductor canal block* (dACB).[11]

Using surface anatomical landmarks and ultrasonography in volunteers, we sought to characterize the relationship of these two commonly described approaches (mtACB and dACB) with the true *"anatomical adductor canal"* in both males and females. The primary outcome was the distance from mtACB to the superior border of AC. Calculated secondary measurements were the distance between the two approaches and the length of AC. We also performed a literature review and provide a narrative summary of the current literature.

Anatomy of the Adductor Canal (Figures 1A & 1B)

Gray's Anatomy describes the AC as a trough-shaped intermuscular tunnel with the proximal end at the apex of the femoral triangle (FT), extending distally as far as the adductor hiatus (AH) – an opening in the adductor magnus muscle through which the femoral blood vessels exit to become the popliteal artery and vein.[12] The FT lies in the anteromedial aspect of the proximal thigh distal to the inguinal ligament. The lateral boundary is the medial margin of sartorius muscle and the medial boundary is the medial margin of adductor longus muscle. The apex of the FT is the intersection of the medial borders of sartorius and adductor longus. The AC is triangular in section and is bounded anterolaterally by vastus medialis muscle and postero-medially by adductor longus and adductor magnus muscles. Its anteromedial boundary (the roof) is a strong and dense fascia called the vasto-adductor membrane (VAM) that extends from the medial surface of vastus medialis to the medial edge of the adductors magnus. The AC contains the superficial femoral artery (SFA) and vein, the descending genicular and muscular branches of the SFA and their corresponding veins, and the saphenous nerve. There is controversy over whether the nerve to the vastus medialis lies within or just outside of the AC.[12-14]

Methods

This descriptive observational study in volunteers was approved by the University of Iowa Institutional Review Board (IRB #201612814). Written informed consent was obtained from all subjects participating in the trial. The trial was registered prior to volunteer enrollment at clinicaltrials.gov (NCT03008564). Sixty volunteers, 30 male and 30 females, were recruited for the study between May 2017 and June 2017. Inclusion criteria were age 18 to 70 years, body mass index less than 35 kg/m^2, and without known anomalies or previous surgeries in the lower limbs that would affect the anatomy of the thigh.

Identifying landmarks and Ultrasound scanning

Both lower limbs of all 60 subjects were measured. Volunteers were positioned supine and the extremity was exposed from anterior superior iliac spine (ASIS) to the knee. The ASIS and the base of patella (PB) were marked on the skin as reference points (Figure 2A). The midpoint of thigh was measured and marked halfway between ASIS and PB. This point corresponded to entry point of the mtACB. The thigh was then scanned under ultrasound guidance (Sparq-Philips, Venue 40, GE Healthcare; M-turbo/Edge, Sonosite; or FlexFocus 400, BK Medical) with a linear probe (6–18 MHz). The probe was placed on the lower medial aspect of the thigh, just above the patella, to identify vastus medialis and the sartorius muscles. The probe was then moved cephalad (proximally) to identify the SFA transitioning to popliteal artery under these muscles. The adductor hiatus was identified and marked at a point at which the superficial femoral artery was seen diving deep and moving away from sartorius and vastus medialis muscles, toward the posterior aspect of the thigh; this point was defined as *the inferior border of adductor canal* (ACinf) (Figure 2B). A point 2.5 cm proximal to ACinf was marked, corresponding to entry point of dACB. The SFA was traced proximally until the medial border of sartorius just overlapped the medial border of the adductor longus muscle. This point was marked as *the superior border of adductor canal* or apex of the femoral triangle (ACsup).

Measurements

Using the base of patella as a reference, the following measurements were obtained on the each marked lower extremity: 1) the length of the thigh (PB-ASIS); 2) the length from patellar base to mid-point of thigh (PB-mtACB); 3) the length from patellar base to the superior border of the adductor canal (PB-ACsup); and 4) the length from patellar base to the inferior border of adductor canal (PB-ACinf). Using the above measurements, we calculated the following distances: 1) *The distance from mtACB to the superior border of AC* [(PB-mtACB) - (PB-ACsup)]; 2) *The distance between the two adductor canal block approaches* [(PB-mtACB) - (PB-dACB)]; and 3) *The length of the adductor canal* [(PB-ACsup) - (PB-ACinf)]. All measurements were made in real time and recorded by the first and second authors (YR and AY) in consensus. Figure 2A shows the skin markings and the three calculated measurements. Figure 2B shows ultrasound images corresponding to superior and inferior borders of the AC.

Statistical Analyses

No *a priori* sample size calculations were done for this observational study on the anatomical points related to adductor canal blocks. Due to the underlying anatomical differences, equal numbers of volunteers from both sexes were included (30 males, 30 females). The average of the right and left leg measurements was calculated for each volunteer and these average values were used for all the subsequent analyses. Normality of the continuous data was tested by the Shapiro-Wilk test and by examining the quantile-quantile plot. Continuous variables are presented as mean and standard deviation for normally distributed data, or as median and interquartile range (25^{th} to 75^{th} percentiles) if the normality assumption was not met. Normally distributed data were compared between males and females using the two independent sample t-test and data not meeting the normality assumption were compared with the Mann-Whitney U test. Statistical analyses were performed using Wizard for Mac software, version 1.9 (Evan Miller). The confidence intervals of the difference in medians were calculated with the SAS software, version 9.4 (Cary, NC, USA).

Results

All planned measurements were made in all subjects (120 extremities in 60 volunteers), and there were no study-related adverse events. There were a total of 120 measurements from 60 subjects. As described above, the average of right and left sides was used for analyses in each volunteer resulting in N=30 for males and N=30 for females.

There was no statistically significant differences in the demographic variables among the volunteers: the mean (± SD) age was 42 ± 5 years and 40 ± 4 years; and the mean (± SD) body mass index was 26 ± 1 kg/$m^2$and 25 ± 2 kg/m^2, respectively for males and females.

Table 1 shows the measured and derived distances separately for the male and female volunteers. The needle entry point for mtACB was proximal to the superior border of adductor canal in 100% of both male (median (IQR), 5.5 cm [4.6-7.0]) and female (6.6 cm [5.8-7.3]) volunteers, with the distance significantly greater in females *(P =* 0.045; median difference: -0.75 cm, 95% CI of the difference in medians, -1.63 to 0.00). All measured lengths were greater in males than females. The length from the mtACB to ACsup was significantly longer in females and the overall AC length was longer in males. The median distance between the needle entry points of mtACB and dACB was 11.7 (10.3-13.0) cm in males and 10.8 (9.9-12.3) cm in females; *(P*=0.23, median difference: 0.625, 95% CI of the difference in medians: -0.25 to 1.50). The length of the adductor canal was 8.4 (7.5-9.5) cm in males and 6.8 (6.0-8.2) cm in females; *(P*<0.01, median difference: 1.5, 95% CI of the difference in medians: 1.00 to 2.25)

Discussion

This volunteer anatomical study compared the point of needle entry of the two most common approaches described for the ACB and found that the mid-thigh approach is proximal to the superior border of adductor canal in both male and female volunteers, and hence outside the true adductor canal. The distal ACB entry point (dACB) was within the true adductor canal. The midthigh approach is proximal to the distal AC approach by approximately 11 cm. To our knowledge, this is the first study evaluating the actual distance between these commonly described approaches to ACB.

Understanding the exact anatomy of the AC is important as multiple needle entry points have been described for AC blocks. Several cadaveric studies and one human volunteer study have previously evaluated the anatomy of adductor canal. Relevant measurements from previous cadaver studies are summarized in Table 2. Anagnostopoulou et al. concluded that the “superior foramen of the AC” (corresponding to the superior border of AC) was at a mean distance of 6.5 cm from the midpoint of thigh.[15] In an earlier study, Horn et al. found the median distance from the proximal patella to the distal end of AC was 10.25 cm (7 to 11.5 cm).[16] In a recent cadaver study, Elazab et al. described a continuous layer of subsartorial fascia called the *fascia vasto-adductoria* in the midthigh.[17] They further subdivided this fascial layer into the a *proximal fascia vasto-adductoria* (a thin, quadrangular layer of fascia stretching between the vastus medialis and adductor longus muscles) and the *distal fascia vasto-adductoria,* also known as *vasto-adductor membrane* (a thick, pentagonal layer arising from the adductor magnus spreading anterolaterally to the vastus medialis muscle). The length of the vasto-adductor membrane in their study was comparable to that from an earlier cadaveric study by Tubbs et al.[18]

In a recent, small (N = 22) ultrasound study in predominantly male volunteers, Wong et al. showed that the midthigh approach was proximal to superior border of AC, but reported a mean AC length of 11.5 cm.[19] In contrast, the median length of adductor canal in our study was 8 cm. Wong et al. stated that the AC is roofed by the vasto-adductor membrane in its entire length, and hence the proximal border of the vasto-adductor membrane marks the beginning of the AC. Using the same principle, we can assume that the distal border of the vasto-adductor membrane marks the distal end of the AC and the vasto-adductor membrane length corresponds to AC length. Previous cadaveric studies have reported a mean vasto-adductor membrane length of 7.6 cm and 7.9 cm, consistent with an AC length of 8 cm in our study.[17,18] The differences in measurements between our study and the Wong et al. study may be related to the method used to localize the inferior border of AC. We used the method described by Manickam et al. to identify the adductor hiatus.[11] By comparison of results it is clear that the inferior border of AC identified by Wong et al. was distal to that used in our study (Table 3). The distance from base of patella to the inferior border of adductor canal in our study (9 cm) also correlates better with previous cadaveric studies. Finally, it is important recognize that ultrasonography relies on generated images of deep structures, and the identified landmarks and measurements may not fully correspond to cadaveric dissections, producing minor differences. This is a limitation of ultrasound studies on anatomical measurements, including our study. Nevertheless, the midpoint of thigh has consistently been reported as proximal to the proximal border of AC and the results from our larger study with both male and female subjects closely correlate with the previous cadaveric studies.

Based on this knowledge of AC anatomy, we reviewed recently published literature to identify various needle entry points described for adductor canal blocks. We searched the PubMed (January 1, 2017–January 31, 2019) using the key word phrase “Adductor canal block.” A total of 115 articles were retrieved; the abstracts and methods of all retrieved articles were reviewed by two authors (YR, AM) and 46 prospective clinical trials were identified and reviewed in detail (Figure 3). Case reports, retrospective studies, cadaveric studies, non-English articles, review articles and meta-analyses were excluded (N = 69) (Included articles are listed in Supplemental Digital Content). The points of needle entry were grouped into 3 different regions (Figures 4A and 4B): i) *proximal blocks*,[20,21] including block entry points that target the SFA after it has just beneath the medial border of the sartorius muscle, or the proximal-thigh approach by Meier et al. involving the needle insertion at a location where the SFA is underneath the medial third of the sartorius muscle; ii) *mid-thigh blocks*,[3,10,20,22] including blocks performed at the midthigh level (between ASIS and base of patella), and the distal approach described Meier et al. where the SFA lies underneath the middle third of sartorius; and iii) *distal blocks*,[11,22,23] including blocks performed at the dACB and other true AC blocks . Figure 4A shows the anatomical locations and Figure 4B shows the corresponding ultrasound image of the levels of these blocks. In 34 out of 40 studies (the needle entry site was not specified in 6 studies), the needle entry point was at or above the midpoint of the thigh, and hence anatomically proximal to the true adductor canal.

Clinical relevance of the blocks at the different locations

Irrespective of the site of injection, and whether it is within the true anatomical adductor canal, it is important to understand if there are clinically significant differences between these block injection sites. In a cadaveric study, Runge et al. injected 10 mL of dye into distal AC in 10 legs and into distal femoral triangle in 3 legs.[24] There was consistent spread of the dye to the popliteal plexus in the distal AC group but no spread of dye into popliteal fossa after the femoral triangle group. Andersen et al and Goffin et al have also demonstrated spread of the injectate to the popliteal fossa with distal AC injection in previous cadaveric studies (Table 4**)**.[25,26] This spread may improve the quality and duration of analgesia of distal AC injections. In a study using 4 fresh frozen cadavers which acted as their own control, Johnston et al. injected 20 mL of dye into one thigh in the distal FT, into the other thigh in the distal AC.[27] When the injectate was introduced into the distal FT, both the saphenous nerve and the nerve to vastus medialis were stained. In contrast, dye administered into the distal AC stained only the saphenous nerve. They concluded that the injection into the distal AC may be suboptimal for knee analgesia as it may spare the nerve to the vastus medialis, while an injection in the distal FT may provide greater analgesia to the knee, but may result in undesirable motor blockade from spread to the vastus medialis nerve.[27] Clinical studies comparing different locations used for ACB in terms of efficacy, undesirable effects, complications and outcomes are limited (Table 5). Three studies compared midthigh injections with more proximal site injections and found that both approaches provided comparable analgesia with minor differences.[20,21,28] A fourth study compared midthigh injection with a distal site injection and showed improved analgesia the day after knee arthroplasty with catheter insertion at the midthigh compared to a more distal insertion point.[22] Another recent study compared catheter insertions at mid FT and proximal AC (2 cm distal to the ACsup) and found no differences in immediate postoperative functional mobility, analgesia, and opioid consumption .[29] In summary research groups that advocate more distal injections believe that analgesia will be better because of blockade of branches of sciatic and obturator nerves while groups that prefer proximal injections believe that consistent blockade of the nerve to vastus medialis is important to block success.

Conclusion

The literature describing adductor canal blocks is conflicting regarding the site of needle puncture, and whether the points of needle entry lie within the true adductor canal. Our study clarifies the exact anatomical locations of the commonly described block approaches relative to the adductor canal. Categorizing these blocks based on true anatomical relationships or as proximal, mid and distal subsartorial nerve blocks, may be a more accurate anatomical description of the actual block. The midthigh approach appears to be the most common approach. Additional clinical studies are required to determine if differences exist in the clinical efficacy, complication rates and outcomes among the blocks performed at the different subsartorial locations for pain relief after knee surgery or other surgical procedures.

List Of Abbreviations

ACB: Adductor canal block

AC: Adductor canal

mtACB: midthigh aductor canal block

dACB: distal adductor canal block

IQR: Interquartile range

CI: Confidence interval

SFA: Superficial femoral artery

FT: Femoral triangle

AH: Adductor hiatus

VAM: vasto-adductor membrane

IRB: Institutional Review Board

ASIS: Anterior superior iliac spine

PB: Base of patella

ACsup: Superior border of adductor canal

ACinf: Inferior border of adductor canal

Declarations

Ethics approval and consent to participate

This prospective study was approved by the Institutional Review Board (IRB #201612814) of the University of Iowa, Iowa City, Iowa, USA. Written informed consent was obtained from all volunteers.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article [and its

supplementary information files]

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable, no funding was received for this study.

Authors’ contributions

YSR and AAM: Designed the study.

YSR, AY and SR: Conducted the study and collected the data.

YSR, CAW and AAM: performed the statistical analysis, analyzed, and interpreted the data, and wrote the manuscript. All authors read and approved the final version of the manuscript.

Acknowledgements

The authors wish to thank Emine O. Bayman, Ph.D. (Associate Professor, Departments Anesthesia,, University of Iowa Carver College of Medicine, and Department of Biostatistics, University of Iowa College of Public Health, Iowa City, IA), for her help with the design and the statistical analyses of this study. The authors also wish to thank Bradley Hindman, MD, (Professor, Department of Anesthesia, University of Iowa Carver College of Medicine, Iowa City, IA), for his editing suggestions of this manuscript.

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Figures

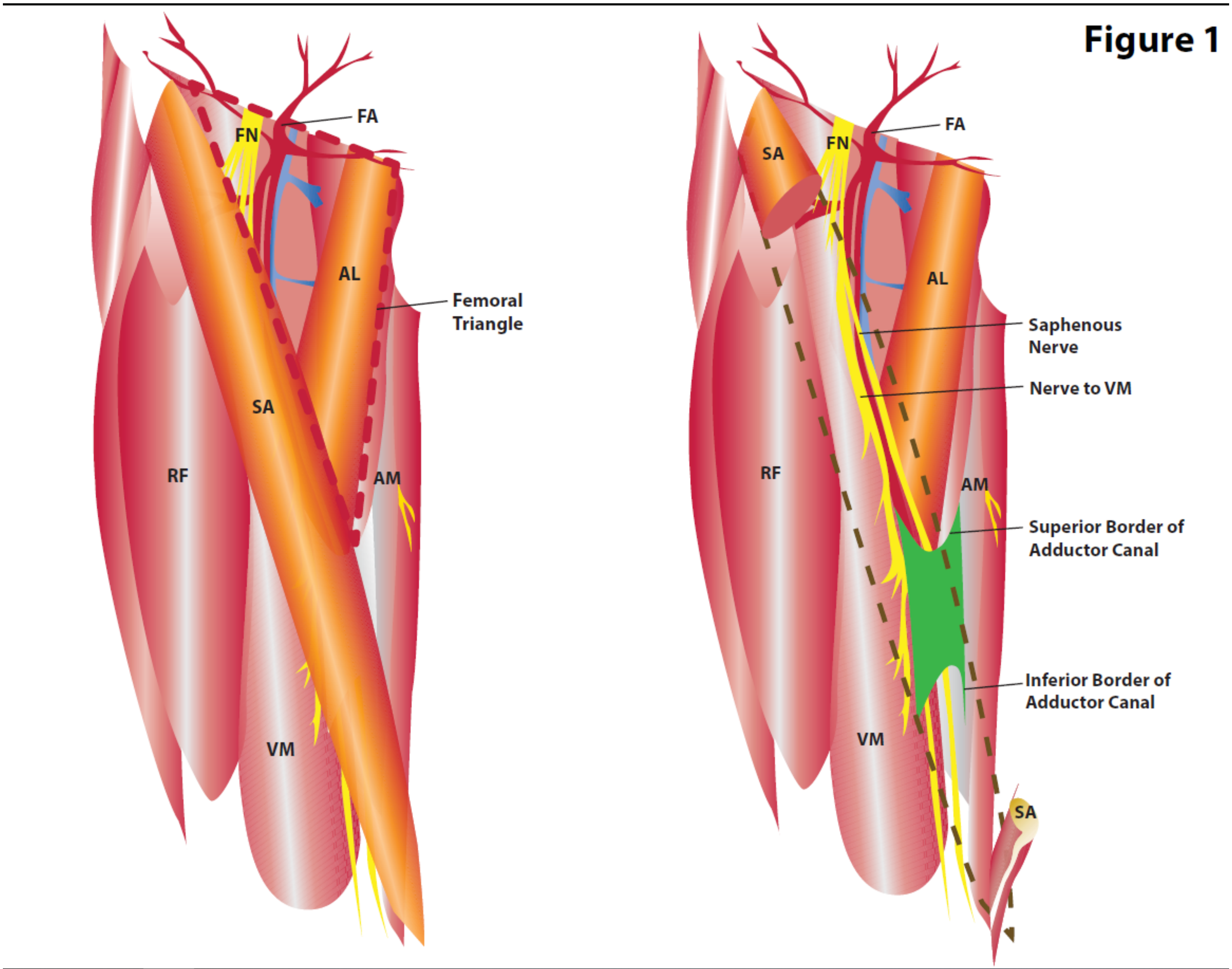

Figure 1

Illustration of boundaries and contents of the femoral triangle (dashed red border), the adductor canal (green) and its superior and inferior borders. SA, sartorius muscle; AL, adductor longus muscle; RF, rectus femoris muscle; VM, vastus medialis muscle; AM, adductor magnus muscle; FN, femoral nerve; FA, femoral artery. SN, saphenous nerve; NVM, nerve to vastus medialis; AC-sup, superior border of adductor canal; AC-inf, inferior border of adductor canal.

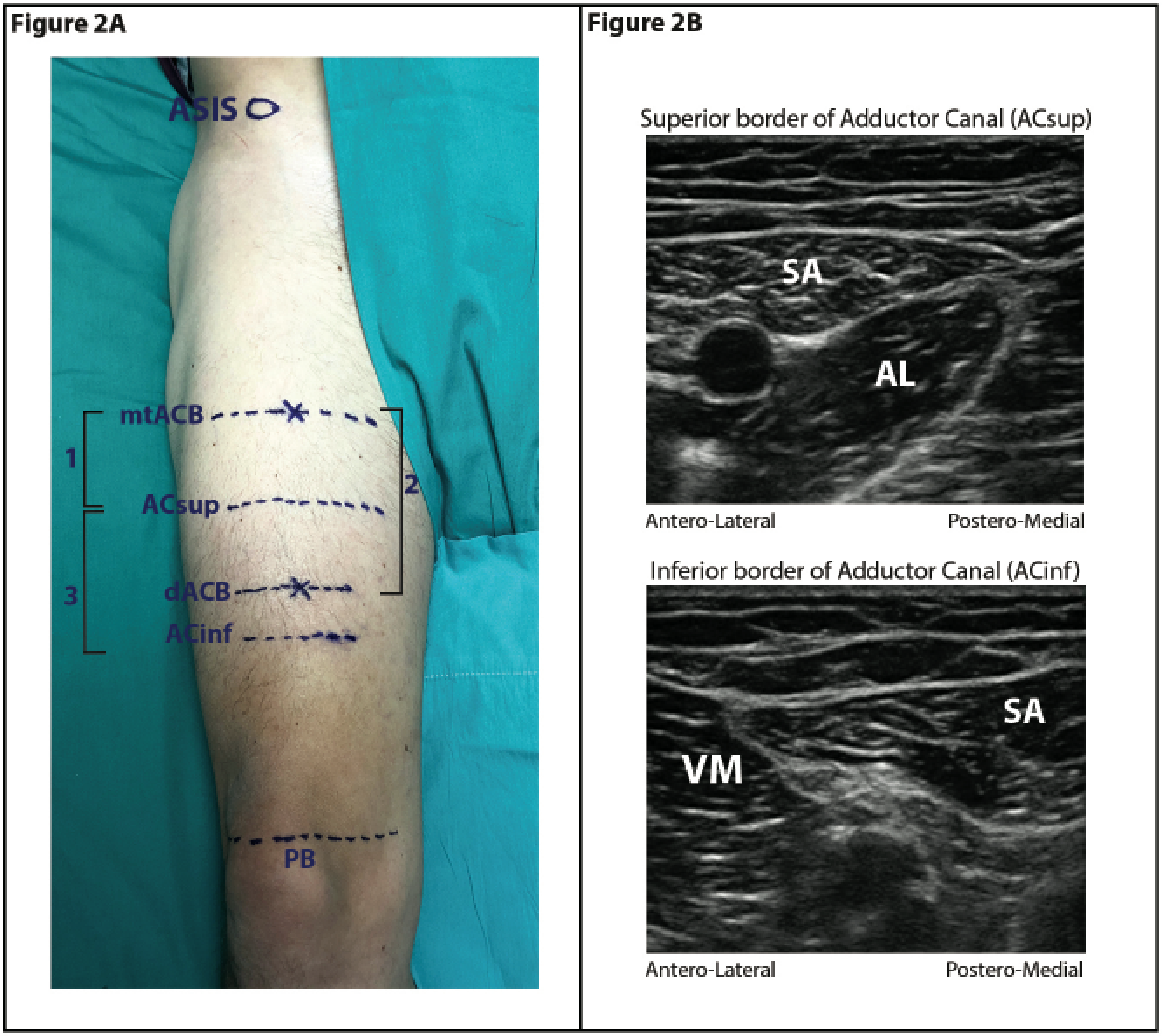

Figure 2

A. Volunteer limb with points marked after ultrasound scanning and palpation of surface land marks. 1: represents distance from midthigh adductor canal block to superior border of adductor canal; 2: represents the distance between the two adductor canal block approaches; 3: represents the adductor canal length. 2B. Ultrasound images with linear transducer at ‘ACsup’ (B1) and ‘ACinf’ (B2). ASIS, anterior superior iliac spine; mtACB, needle entry point for midthigh adductor canal block; ACsup, superior border of adductor canal; dACB, needle entry point for distal adductor canal block; ACinf, inferior border of adductor canal; PB, base of the patella; SA, sartorius muscle; AL, adductor longus muscle; VM, vastus medialis muscle.

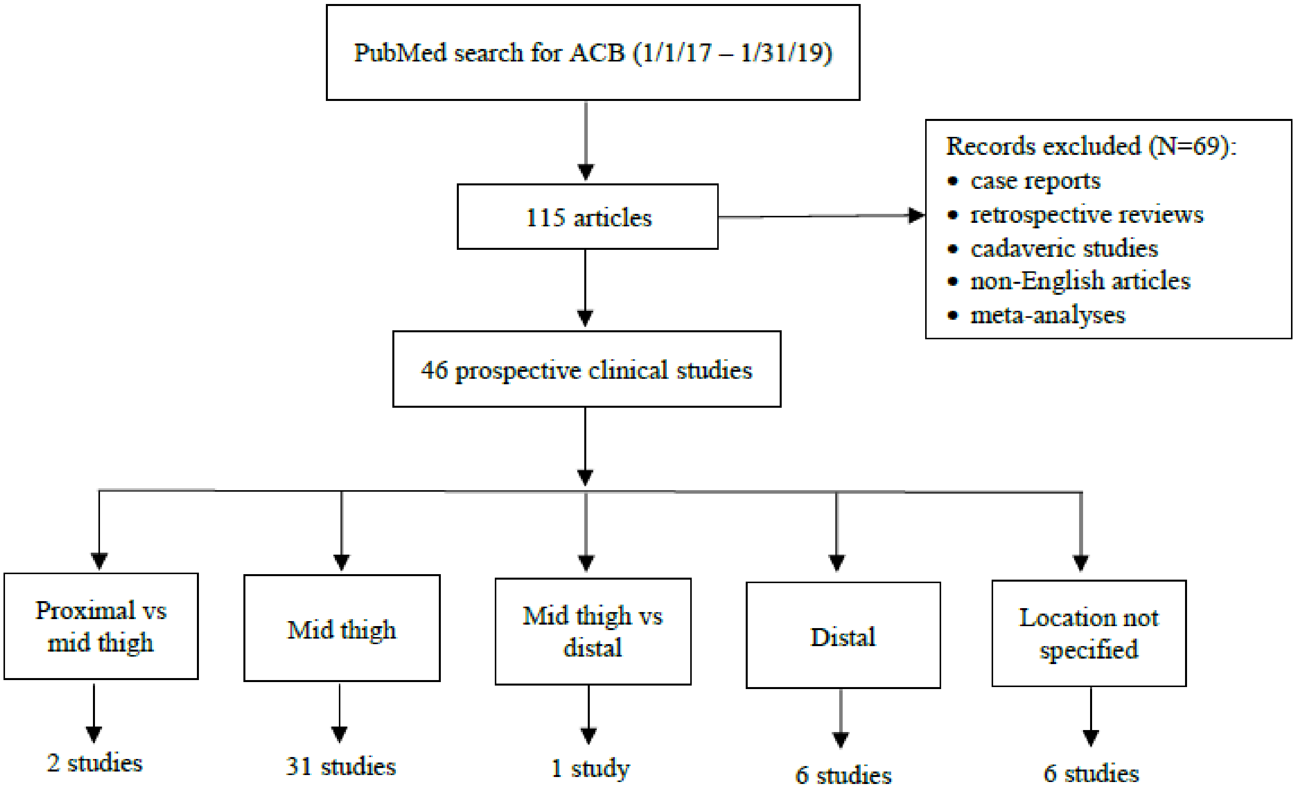

Figure 3

Details of PubMed search from January 1, 2017 to January 31, 2019 using “adductor canal block.”

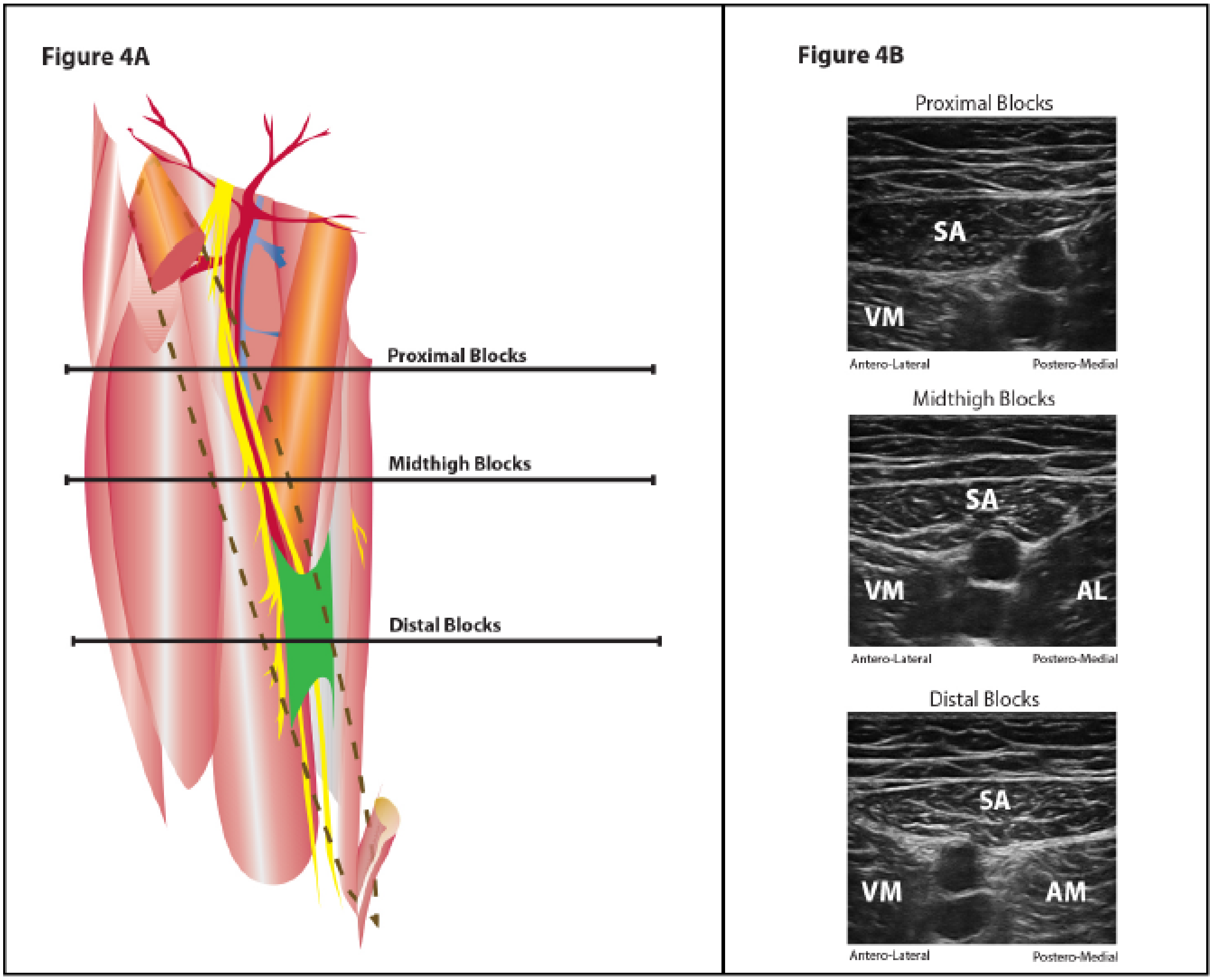

Figure 4

A. Illustration showing various needle insertion sites used for adductor canal block in prospective clinical trials and their relationship to the adductor canal. 4B. Sample ultrasound images with a linear transducer at different needle insertion sites: Proximal blocks, Midthigh blocks, and Distal blocks. SA, sartorius muscle; AL, adductor longus muscle; VM, vastus medialis muscle; AM, adductor magnus muscle.`

Supplementary Files

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- ACBTable3.pdf
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