Gurbuz and Colak *BMC Anesthesiology* (2025) 25:144
https://doi.org/10.1186/s12871-025-03020-2

BMC Anesthesiology

RESEARCH

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Evaluation of inguinal sonoanatomy regarding pericapsular nerve group (PENG) block in children: the relation of femoral artery, femoral nerve, lateral femoral cutaneous nerve and iliopsoas notch

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Abstract

Background Pericapsular nerve group (PENG) block is a novel technique that provides analgesia in hip surgeries while preserving motor function. This study aimed to identify developmental differences and variations regarding PENG block sonoanatomy in the inguinal region in children.

Methods A total of 150 children between 28 days and 18 years were included in this prospective, observational, descriptive study. The participants were divided into six groups according to growth and development periods. Ultrasonographic measurements representing block depth, needle length, and the vicinity of femoral nerve (FN) and femoral artery (FA) to the block area were collected.

Results Block depth: 16.2 ± 4.0 mm in infants (28 days–12 months); 33.5 ± 6.1 mm in adolescents (145–215 months). Needle length: 24.2 ± 5.9 mm in infants; 39.3 ± 6.6 mm in adolescents. The distance of FA to the block area: 4.4 ± 2.0 mm in infants; 11.6 ± 5.7 mm in adolescents. The distance of FN to the block area: 0.7 ± 0.8 mm in infants; 2.9 ± 4.0 mm in adolescents. FN-FA distance: 2.2 ± 1.4 mm in infants; 3.8 ± 1.8 mm in adolescents. In 49/150 (32.7%) cases the FN overlapped the perpendicular line between iliopsoas notch and skin. The lateral femoral cutaneous nerve (LFCN) was involved in the ultrasound frame in 11/50 (22%) children under the age of three.

Conclusions Especially in children under three years of age, LFCN should be visualized during the pre-block preparation phase. The out-of-plane approach is not recommended in the PENG block due to the FN's alignment on the path of a vertical needle trace.

Trial registration NCT04860479.

Keywords Analgesia, Anesthesia, Hip Joint, Pediatric Anesthesia, PENG Block, Pericapsular nerve group block, Regional Anatomy, Regional Anesthesia, Ultrasonography

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Introduction

Developmental hip dysplasia and epiphyseal fractures are the two most common reasons for hip surgeries performed in pediatric patients [1]. The postoperative period of hip surgeries can be extremely painful. If the analgesia provided is inadequate, it can lead to dissatisfaction among both patients and parents, delayed wound healing, and an extended hospital stay [2]. It has been noted that opioid use is relatively high in children who undergo orthopedic surgery [3]. Additionally, research suggests that pain intensity above 3.0 points and pain unpleasantness are associated with over twice the risk of moderate to severe chronic postoperative pain in children [4]. Therefore, regional block techniques are recommended as part of a multimodal analgesia strategy in pediatric anesthesia.

Pericapsular nerve group (PENG) block is a novel regional method aiming to block the articular branches of femoral and obturator nerves while preserving the motor function of the lower limb. The PENG block has become a popular method for adult hip surgeries because of its effectiveness and low risk of complications. However, there are only a few case reports on its use in pediatric patients (Table 1) [5–13].

The relative proportions of the pelvis, femur, and surrounding soft tissues in children differ from adults due to ongoing growth. For instance, the femoral nerve's (FN) proximity to the inguinal ligament and iliopsoas notch changes as children grow, increasing the risk of nerve or vascular injury. These developmental differences, such as underdeveloped muscle mass and smaller anatomical landmarks, complicate the identification of safe injection sites for regional blocks like the PENG block [14, 15]. The potential for nerve-overlap and variability in the position of the lateral femoral cutaneous nerve (LFCN) may lead to inadvertent nerve damage or ineffective blocks [15, 16].

The critical elements for successful nerve blocks and reducing possible complications are choosing the correct needle size, using local anesthetics with adequate volume and concentration, using proper equipment, and, perhaps most importantly, knowing the functional regional block anatomy. Therefore, the primary objective of this study was to evaluate the differences in block depth and needle length, as well as FN and the femoral artery (FA) relation, in the inguinal region during the developmental process in children aged 28 days to 18 years. The secondary objective was to identify neurovascular variations in the sonoanatomy and discuss these findings regarding the possible complications of the PENG block.

Methods

After approval of the study protocol by the institutional ethics committee (date: 31.03.2021, decree: 2011-KAEK-25 2021/03–13), this prospective observational descriptive study was held in a tertiary-level training and research hospital between April 2021 and January 2024. The study was registered on www.clinicaltrials.gov with the ID NCT04860479 (22 April 2021). The study was conducted in accordance with the Helsinki Declaration and reported in adherence to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for observational studies [17]. Informed parental consent and child assent were obtained according to the guidelines set by the Institutional Review Board, and compliance with local laws related to pediatric clinical trials was ensured.

Patient selection

Inclusion and exclusion criteria

The study involved pediatric patients between the ages of 28 days and 215 months who underwent surgery for any reason in the operating theater. Patients with structural anomalies (e.g., congenital hip dysplasia, femoral deformity), and growth-affecting diseases (e.g., mucopolysaccharidosis, cerebral palsy) were excluded from the study. Additionally, patients who were scheduled to undergo surgery in the hip or groin area, those who had previously undergone surgery in this area, and individuals who did not consent to participate were also excluded.

Age groups

The children included in the study were evaluated across age groups based on their growth and physical development periods. Accordingly: Group A: Infants: 28 days–12 months; Group B: Young children: 13–36 months; Group C: Preschool: 37–72 months; Group D: School-age: 73–108 months; Group E: Pre-adolescents: 109–144 months, Group-F: Adolescents: 145–215 months.

Evaluation of ultrasound images

Ultrasound images were captured using a portable, wireless Clarius™ L7 ultrasound device with a linear probe of 4–13 MHz frequency and a probe length of 4 cm. The Clarius™ application on the connected tablet was used to measure the distances between anatomical structures. To ensure accuracy, the image was transferred to the MicroDicom Viewer software, and a second measurement was taken. Finally, the average of both measurements was calculated to minimize the margin of error.

Table 1 Summary of literature on pediatric PENG block for hip pain

No	1st author, publication date, country	Number of patients	Indication	Age, weight	Local anesthetic	Additional intervention	Outcome
1	Orozco, Apr'19, Colombia	1	Osteosynthesis material removal	8 years	10mL %0,5 Bupivacaine + Epinephrin	FN: 7,5mL %1 Lidocaine + 7,5mL %0,75 Levobupivacaine LFCN: 2,5mL %1 Lidocaine + 2,5mL %0,75 Levobupivacaine	The pain score until PO 72nd hour is 2/10
2	Aksu, May'20, Turkey	1	Congenital hip dysplasia	8 years, 15kg	10mL %0,25 Bupivacaine	None	No analgesics except for 10mg/kg oral ibuprofen at the PO 10th hour
3	Ince, May'20, Turkey	1	Congenital hip dysplasia	4 years, 17kg	8mL %0,25 Bupivacaine	ESP (L4): 12mL %0,25 Bupivacaine	Paracetamol 10mg/kg (1 per 6 h) Max FLACC score in the first PO 24 h is 1/10
4	Wyatt, July'20, Brazil	1	Proximal femur fracture	9 years, 45,7kg	14mL %0,25 Bupivacaine	PENG catheter: %0,1 Ropivacaine, 6mL/h infusion	The FLACC score in the first 12 h is 0/10. Able to attend physiotherapy on PO day 1
5	Wyatt, Nov'20, USA	1	Sickle cell crisis	15years, 64kg	16mL %0,25 Bupivacaine + Dexmedetomidine	FN: 16mL %0,25 Bupivacaine + Dexmedetomidine	No need for opioids in the first 24 h. The pain score is 0/10
6	Anido Guzmán, Sep'21, Spain	1	Varus derotation osteotomy and adductor tenotomy	5 years, 16kg	10 mL %0,25 Bupivacaine (bilateral)	LFCN: 3mL %0,25 Bupivacaine (bilateral)	The FLACC score is 0–1/10 in the first 24 h. Paracetamol 250mg for once
7	Yörükoğlu, June'22 Turkey	5	Congenital hip dysplasia	10 to 20 months	0,5mL/kg %0,25 bupivacaine	None	PO paracetamol in 2 cases In the first 24 h, FLACC score is 0–2/10, in all cases
8	Xu, Nov'22, China	1	Congenital hip dysplasia	7 years, 16kg	0,2% ropivacaine 2.5 ml/kg	None	Patient controlled analgesia with sufentanil 0,05μg/kg/h and granisetron 2μg/kg/h The pain score is 2/10 in the PO first 24 h
9	Domagalska, Feb'23, Poland	2	1st Case: Paralytic dislocation 2nd Case: Congenital hip dysplasia	1st Case: 4years, 14.3kg, 2nd Case: 2years, 18kg	1st Case: 7,5mL %0,2 ropivacaine 2nd Case: 5mL %0,2 ropivacaine	None	1st Case: 200mg paracetamol (1 per 6 h) + 200mg metamizole at the PO 12th hour Max FLACC score is 3/10 2nd Case: 200mg paracetamol (1 per 6 h) Max FLACC score is 2/10

PENG Pericapsular nerve group, *FN* Femoral nerve, *LFCN* Lateral femoral cutaneous nerve, *PO* Postoperative, *ESP* Erector spinae plane block, *FLACC*: Face – legs – activity – cry – consolability

Data acquisition

Demographic data

The ages of the children were calculated and recorded in months and years from their birth date to the day of measurement. The weight of each child was measured with a standard scale during hospitalization and recorded in kilograms and grams. Height measurements were taken with a standard tape measure in the operating room. Weight and height percentiles were utilized to standardize the broad range of developmental differences across ages during childhood, facilitating data interpretation. Height and weight percentiles were calculated using the PediTools calculator (PediTools: Clinical tools for pediatric providers) based on the Centers for Disease Control and Prevention (CDC) Growth Charts.

Ultrasound measurements

Evaluations regarding neurovascular structures, their distances to the block area, and the characteristics of the block area were made by considering possible complications, such as FA puncture or FN and LFCN injury due to technical errors in PENG block application and differences in child development.

Ultrasonography was carried out with the patient lying supine, and the leg was in 10–15° external rotation. The ultrasound probe was placed in transverse orientation on the anterior inferior iliac spine at the level of the iliopsoas notch and then rotated approximately 45° to align it with the pelvic rim. After capturing the best possible image, measurements were taken. Care was taken to leave the iliopsoas notch in the middle of the screen. To reduce the possibility of measurement errors when measuring the distance between the iliopsoas notch and the skin, we attempted to minimize pressure applied to the ultrasound probe, while still maintaining the round shape of the femoral vein (FV).

Due to the individual anatomical variations in the iliopsoas notch and the iliopsoas tendon, these structures may not appear in the same standard shape on ultrasonography for every patient [18, 19]. Therefore, an imaginary injection point, located at the lateral edge of the iliopsoas tendon, was identified after capturing the relevant image for measurement. Then a perpendicular line was drawn from this point (on the iliopsoas notch) to the skin. This line was accepted as the reference line. At this stage, the distances of the FA and FN to the reference line, the distance between the most lateral edge of the FA and the most medial edges of the FN, and the distance between the iliopsoas notch and the most lateral corner of the probe were measured (Fig. 1). It was recorded whether the LFCN was visible on the ultrasonography image.

The reference line between the iliopsoas notch and the skin determines the block depth. Additionally, the distance of the FA and FN to this reference line indicates the distance of these structures to the block area. Finally, the distance between the iliopsoas notch and the most lateral corner of the probe indicates the needle length.

Sample Size

Since there had been no previous studies on FN-FA distance in the pediatric population, a single-arm study conducted in adults was used as a reference [20]. Accordingly, the average distance between the FA and FN was 0.42 ± 0.42 cm in adults, and this value was strongly correlated with age. Consequently, we developed an H_1 hypothesis based on the expectation that there would be at least a 50% difference between the average measurements of FA and FN distances in adults compared to children. The sample size was calculated using the G*Power (v.3.1.9.4) analysis software. To achieve a power of 0.90 with an effect size of 0.3 for a medium effect and the assumption of a two-sided type-I error of 0.05, a total of 138 samples were required for a single-arm study. Considering possible dropouts and our additional objectives of controlling for possible subgroup analysis, 150 patients were planned to be included in the study using the quota sampling method.

Statistical analysis

Statistical evaluation was performed using the SPSS 25.0 software (IBM SPSS Statistics for Windows, v.25.0. Armonk, NY: IBM Corp., 2017). Normality distributions of the data were analyzed using Kolmogorov–Smirnov and Shapiro–Wilk tests. In the tables showing demographics, descriptive data are expressed as means ± SD for numerical variables and as counts and percentages for categorical data. The intra- and inter-group relationship of demographic variables and ultrasound measurements according to age groups was evaluated with the non-parametric Spearman correlation test, since parametric test criteria were not met. The Kruskal–Wallis H test was used to detect the difference of the ultrasound measurements between the age groups. The final *P* values of the multiple comparison tests were adjusted with Bonferroni correction. A *P* value of less than 0.05 was considered statistically significant.

Results

Of 168 patients assessed for eligibility, 18 were excluded based on the established exclusion criteria. Of the 18 patients excluded from the study, 11 had undergone bilateral inguinal hernia repair or orchiopexy surgeries; four had severe developmental disorders resulting from cerebral palsy; two patients were admitted due to traumatic femoral head and pelvic fractures; and one patient with mucopolysaccharidosis type 1 (Hurler syndrome) underwent surgery for a giant inguinal hernia repair.

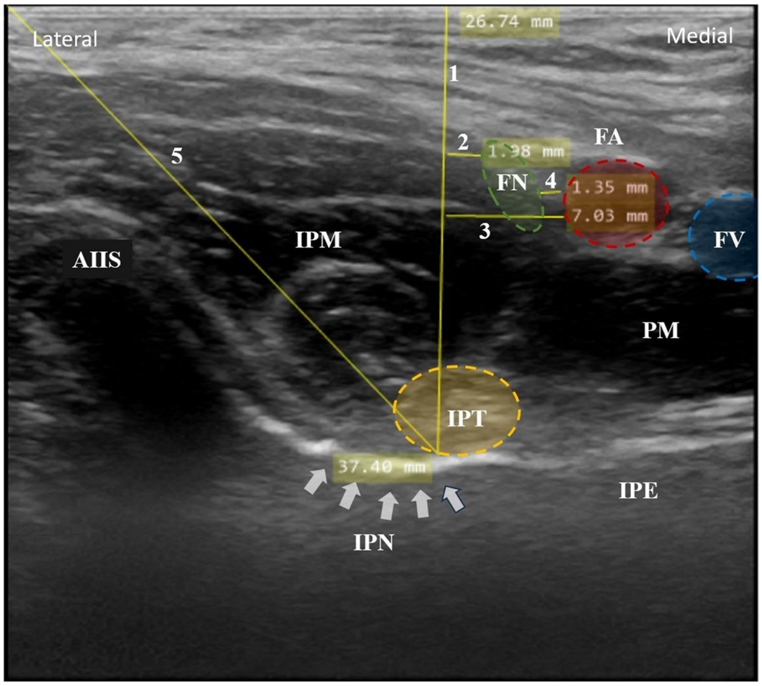

Fig. 1 Ultrasound image of a 11-year-old girl 32 kg in weight and 138 cm in height. The distance between; 1: the iliopsoas notch and the reference line, 2: the femoral nerve and the reference line, 3: the femoral artery and the reference line, 4: the femoral artery and the femoral nerve, 5: the iliopsoas notch and the most lateral corner of the probe. White arrows indicate the iliopsoas notch. FA: femoral artery, FN: femoral nerve, FV: femoral vein, IPE: iliopubic eminence, IPM: iliopsoas muscle, IPN: iliopsoas notch, IPT: iliopsoas tendon, PM: pectineus muscle, AIIS: anterior inferior iliac spine

A total of 150 cases were evaluated across six groups, with 25 cases in each. All samples comprised 67 (44.7%) girls and 83 (55.3%) boys. Demographic data and ultrasound measurements of the participants are presented in Table 2.

The vicinity of the block area to the FN and LFCN is presented in Table 3. The LFCN involved in the ultrasound image in 11 (50%) children below the age of three years (Fig. 2). In 49/150 (32.7%) cases, the FN overlaps the reference line (Figs. 3 and 4).

Table 2 Demographic data and ultrasound measurements in age groups

Group	A ($n=25$)	B ($n=25$)	C ($n=25$)	D ($n=25$)	E ($n=25$)	F ($n=25$)
Age Range	*28days–12 months*	*13–36 months*	*37–72 months*	*73–108 months*	*109–144 months*	*145–215 months*
Demographic data						
Gender, *girl*	12 (48.0)	14 (56.0)	8 (32.0)	12 (48.0)	10 (40.0)	11 (44.0)
Age, *years*	0.5 ± 0.3	1.9 ± 0.6	4.4 ± 0.9	7.5 ± 0.9	10.8 ± 0.8	15.8 ± 1.9
Height, *cm*	66.7 ± 7.8	85.8 ± 7.7	104.7 ± 7.4	129.9 ± 8.4	142.2 ± 8.2	165.6 ± 10.6
Height percentile, *%*	47.1 ± 29.6	52.9 ± 32.9	51.7 ± 28.7	75.0 ± 21.5	48.6 ± 30.3	53.2 ± 27.0
Weight, *kg*	7.7 ± 2.3	12.4 ± 2.3	16.8 ± 2.7	26.6 ± 5.4	35.2 ± 6.9	55.9 ± 12.2
Weight percentile, *%*	48.2 ± 30.4	49.6 ± 34.3	44.5 ± 25.8	60.7 ± 24.1	45.2 ± 29.1	48.7 ± 29.0
Ultrasound measurements						
FN – FA, *mm*	2.2 ± 1.4	2.3 ± 0.9	2.9 ± 1.3	3.1 ± 1.6	3.3 ± 1.5	3.8 ± 1.8
IPN – skin, *mm*	16.2 ± 4.0	17.2 ± 2.6	18.6 ± 3.8	23.7 ± 5.5	25.4 ± 8.4	33.5 ± 6.1
Ref – FA, *mm*	4.4 ± 2.0	4.9 ± 1.3	6.9 ± 2.1	8.6 ± 2.5	9.5 ± 3.8	11.6 ± 5.7
Ref – FN, *mm*	0.7 ± 0.8	1.5 ± 1.5	1.9 ± 1.3	1.9 ± 1.8	2.4 ± 2.5	2.9 ± 4.0
IPN – US, *mm*	24.2 ± 5.9	26.7 ± 4.7	26.5 ± 5.7	28.4 ± 4.8	33.1 ± 5.9	39.3 ± 6.6

Values are presented as mean ± SD or counts (%)

FA Femoral artery, *FN* Femoral nerve, *IPN* Iliopsoas notch, *Ref* Reference line, *US* Ultrasound

Table 3 The vicinity of the block area to the femoral and lateral femoral cutaneous nerves

Group	A ($n=25$)	B ($n=25$)	C ($n=25$)	D ($n=25$)	E ($n=25$)	F ($n=25$)	Total ($n=150$)
Age Range	28days–12 months	13–36 months	37–72 months	73–108 months	109–144 months	145–215 months	28days–215 months
FN overlapping the reference line, n (%)	10 (40)	6 (24)	6 (24)	7 (28)	10 (40)	10 (40)	49 (32.7)
LFCN visible in the image, n (%)	8 (32)	3 (12)	-	-	-	-	11 (7.3)

Values are presented as counts (%)

FN Femoral nerve, *LFCN* Lateral femoral cutaneous nerve

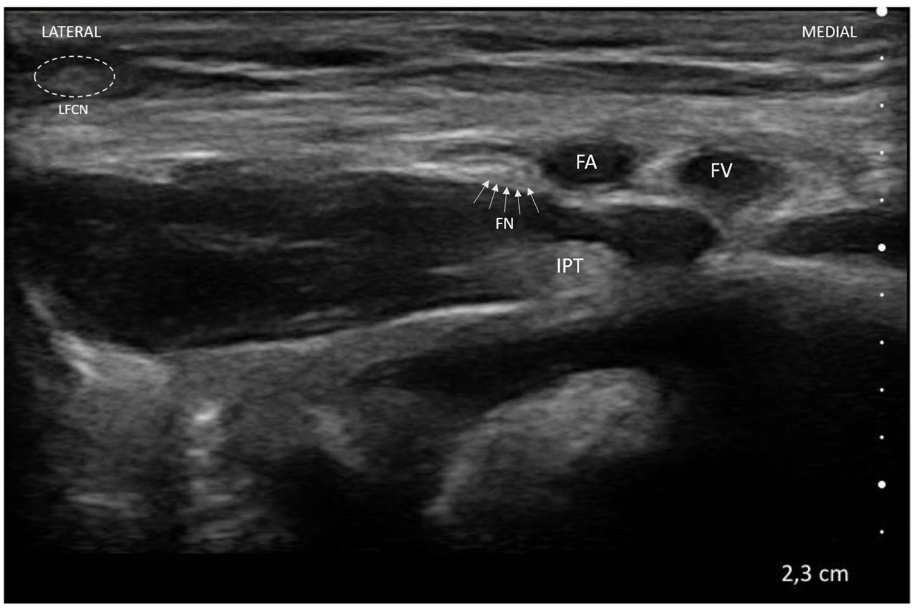

Fig. 2 Ultrasound image of a 4-month-old male infant 8.5 kg in weight and 68 cm in length. The lateral femoral cutaneous nerve (LFCN) is included in the image and is located on the needle trace. White arrows point to the femoral nerve. Dashed line encircles LFCN. FA: femoral artery, FN: femoral nerve, FV: femoral vein, IPT: iliopsoas tendon, LFCN: lateral femoral cutaneous nerve

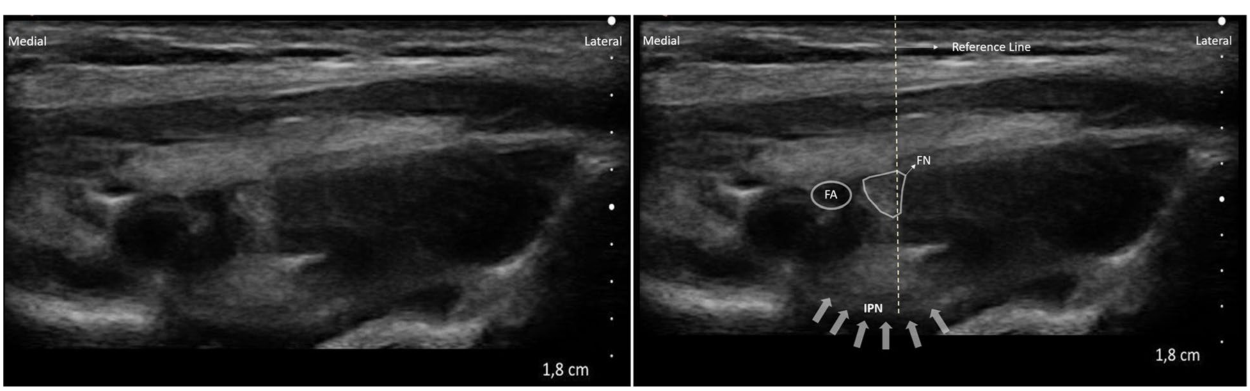

Fig. 3 Ultrasound image of a 2-month-old baby boy 4.5 kg in weight and 56 cm in height. The reference line drawn between the skin and the iliopsoas notch passes over the femoral nerve. White arrows point to the iliopsoas notch. FA: femoral artery, FN: femoral nerve, IPN: iliopsoas notch

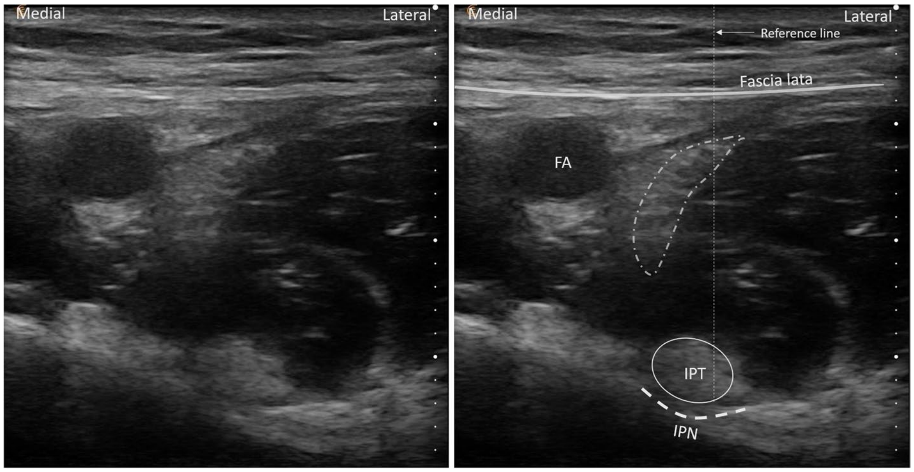

Fig. 4 Ultrasound image of a 17-year-old girl 54 kg in weight and 163 cm in height. The reference line passes over the femoral nerve. FA: femoral artery, FN: femoral nerve, IPN: iliopsoas notch, IPT: iliopsoas tendon

The results of the correlation analysis between ultrasound measurements and demographic data for all cases (28 days—215 months) are presented in Table 4. The study revealed that the distance between the FN and FA had a statistically positive and moderate correlation with age, height, and weight (r: 0.364, $P<0.001$; r: 0.372, $P<0.001$; r: 0.360, $P<0.001$, respectively). Additionally, the average FN-FA distance across all 150 cases was calculated to be 2.9 ± 1.49 mm, supporting the initial hypothesis. It was also noted that the distance between the iliopsoas notch and the skin, the distance of the FA to the reference line, and the distance between the iliopsoas notch and the most lateral corner of the ultrasound probe were positively and strongly correlated with age, height, and weight ($r>0.5$, $P<0.001$). The distance of the FN to the reference line was positively and weakly correlated with age, height, and weight (r: 0.221, P: 0.007; r: 0.207 P: 0.011; r: 0.195; P: 0.017, respectively).

Each age group was re-evaluated individually to determine which parameters influenced the measurements more significantly within each group. However, no correlation was found between ultrasound measurements and gender, height, height-percentile, weight, and weight-percentile within any age group ($P>0.05$).

Discussion

While the existing literature on PENG block in children is quite limited, attention has been drawn to possible complications due to the anatomical proximity of the block site to some significant structures. Accordingly, the main result obtained from this study, which evaluates the relationship of the PENG block area with critical anatomical

Table 4 Correlation between the demographic variables and ultrasound measurements for all cases

28 days – 215 months (*n* = 150)		Gender, girl	Age	Height	Height Pct	Weight	Weight Pct
FN – FA	*r s*	0.031	0.364	0.372	0.075	0.360	0.027
	P	0.711	< 0.001*	< 0.001*	0.360	< 0.001*	0.739
IPN – skin	*r s*	0.020	0.716	0.714	0.096	0.719	0.089
	P	0.811	< 0.001*	< 0.001*	0.244	< 0.001*	0.278
Ref – FA	*r s*	0.013	0.649	0.645	0.104	0.621	-0.020
	P	0.873	< 0.001*	< 0.001*	0.207	< 0.001*	0.807
Ref – FN	*r s*	-0.056	0.221	0.207	-0.009	0.195	-0.086
	P	0.496	0.007*	0.011*	0.912	0.017*	0.298
IPN – US	*r s*	0.055	0.606	0.610	0.057	0.604	0.035
	P	0.502	< 0.001*	< 0.001*	0.489	< 0.001*	0.667

Kolmogorov- Smirnov test was used to assess the normality assumption for all cases (age from 28 days to 215 months; *n* = 150). Values marked with * indicate statistically significant differences (*P* value < 0.05) by using Spearman correlation test (*r s*)

FA Femoral artery, *FN* Femoral nerve, *IPN* Iliopsoas notch, *Pct* Percentile, *Ref* Reference line, *US* Ultrasound structures, is that structures such as the LFCN may be found on the needle trace in younger children. Additionally, the FN's alignment on the vertical line makes the out-of-plane technique unviable.

PENG block has become very popular in hip surgeries as it provides adequate analgesia in the hip joint while preserving the motor function of the quadriceps muscle. Motor weakness in the lower extremities has been reported in three adult cases so far after PENG block [21, 22]. In the first of these cases, the block was technically difficult; in the second, the needle was too medialized; and in the third, a higher volume of local anesthetic was used than the recommended amount. In case reports about PENG block in children, the authors used local anesthetic at a volume of 0.3–0.5 ml/kg and did not report any complications (Table 1) [5–13]. However, although no dose-finding studies have been conducted in children, undesirable effects may be encountered considering the proximity of the block area and other critical anatomical structures. Furthermore, based on the findings of this study, the expected needle length and block depth increase as the height, weight, and age increase. Accordingly, the average block depth ranges from 16.2 ± 4.0 to 33.5 ± 6.1 mm, and the average needle length ranges from 24.2 ± 5.9 to 39.3 ± 6.6 mm. Therefore, the specified block depth and needle length can assist in selecting the proper needle size. These findings can also help determine the appropriate volume of local anesthetic for children in such a small area without affecting motor nerves.

Previous reports have pointed out that the FN and LFCN may be accidentally damaged by the needle during the PENG block [23]. The FN is most likely found as sandwiched between the fascia iliaca and the iliopsoas muscle. However, in some cases, it has been shown that it can also be seen in the belly of the iliopsoas muscle [24]. In such cases, since the FN will be located more laterally than is usually expected, the possibility of it being on the needle trace in the in-plane approach will increase. Although the FN was not seen on the trace drawn for the in-plane approach in any patient in our study, individual differences should still be considered.

Although an in-plane approach with the help of ultrasound is preferred in PENG block application, previous studies have stated that it can also be applied with an out-of-plane approach or landmark method (vertical entry) [25–27]. However, according to the results of our study, in a total of 49/150 (32.7%) cases, regardless of age group, the FN remains on the reference line drawn perpendicularly from the iliopsoas notch to the skin. Additionally, the average distance between the FN and the reference line varies between 0.7 ± 0.8 and 2.9 ± 4.0 mm. Based on these results, reaching the target in the PENG block with a vertical needle entry without needle contact with the FN is almost impossible. Also, there is a risk of accidental vascular puncture due to the proximity of the FA to the reference line.

Another potential complication highlighted with PENG block is LFCN damage. In our study, the LFCN was in the screen image in 11/50 (22%) children under the age of three. In fact, this condition can also be used as an advantage in cases where the LFCN is desired to be blocked in addition to the PENG block, as two blocks can be performed simultaneously with a single needle insertion [15]. However, if the LFCN is failed to be noticed, it may be unintentionally damaged. While awake, adult patients can express paresthesia in the anterolateral part of the thigh when the needle contacts with the LFCN during the PENG block; however, the most significant handicap in children is that the block is performed while under general anesthesia.

Another possible complication suggested with the PENG block is bladder injury in patients with full bladders when the needle is too medialized [14]. In our study, the bladder was not included in the ultrasonography image in any of the 150 children examined. However, it can still be considered a potential complication in the presence of a distended bladder.

The FA and FN distances have been evaluated in several studies before. It has been shown that when the thigh is placed in 45° external rotation, the distance between the FA and FN increases [28]. Another clinical study stated that the distance between the projections of the FA and FN on the skin was the width of the 5th distal interphalangeal joint of the person's dominant hand [29]. In a cadaver dissection study, it was shown that the FA and FN were just adjacent to each other in 12% of the cases at the inguinal ligament level and 71% of the cases at the inguinal fold level, and the distance between them varied between 0.0–13.0 mm [30]. Yoshimura et al. stated that the average distance between the FA and FN at the inguinal fold level is 0.42 ± 0.42 (min. 0.46—max. 1.43) cm and that this distance increases in adults with age due to a decrease in iliopsoas muscle volume [20]. However, since the iliopsoas muscle volume in children increases until late adolescence, the cause-effect proposition made by Yoshimura et al. is not valid for this study [31]. Therefore, for the pediatric age group in this study, the distance between the FA and FN is positively and moderately correlated with the volumetric development of tissues and the increase in body surface area. In addition to the PENG blocks, the proximity of the FN and FA increases the risk of FN injury during intra-arterial cannulations and FA injury during FN blocks.

The study has some limitations. Deviations may occur in ultrasound measurements depending on the physician, so there is always a margin of error. For this reason, ultrasonography was performed by a single person, thus trying to eliminate inter-individual differences. Additionally, two separate software were used to reduce the margin of error between measurements. Furthermore, since ultrasonographic evaluations were not made comparing right and left, morphological differences between the dominant and non-dominant sides could not be determined. Another limitation of this study is the sampling method. While quota sampling is easy and quick, the drawbacks are the lack of randomization and the likelihood of bias. Lastly, the entire LFCN could not be localized with ultrasound since only the obtained ultrasound image was studied. Therefore, the actual number of LFCNs on the needle trace in young children may be higher than reported in our study.

This study emphasizes the key anatomical considerations of the PENG block in children. However, future studies focusing on determining the minimum effective dose and volume of local anesthetics required for optimal efficacy and evaluating the safety profiles associated with clinical applications in pediatric populations are needed to enhance clinical practice. These investigations will contribute to refining the technique and ensuring improved pediatric patient outcomes.

Conclusions

As a result, block depth, needle length, the proximity of FA and FN to the block area, and the distances of FA and FN are influenced by weight, height, and age, but not by gender in pediatric patients. The average of these measurements can help determine the block depth and the needle size. The LFCN should be localized during the block preparation phase, particularly in children younger than three years old, for a safe PENG block. Depending on the relationship of FN with the block area, the out-of-plane approach is not recommended in the PENG block.

Abbreviations

FA Femoral artery
FN Femoral nerve
FV Femoral vein
LFCN Lateral femoral cutaneous nerve
PENG Pericapsular nerve group

Acknowledgements

Nothing to declare.

Authors' contributions

H. G.: The idea of research, conduction of the study, collection of data, interpretation of data, and preparation of the manuscript. T. C.: The design of the study, drafting, revision, and the final approval of the manuscript.

Funding

The authors have no sources of funding to declare for this manuscript.

Data availability

The data sets used in this research may be made available upon reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committees of Bursa Yuksek Ihtisas Training and Research Hospital (date: 31.03.2021, decree: 2011-KAEK-25 2021/03–13) and was registered on www.clinicaltrials.gov with the ID NCT04860479 (22 April 2021). Informed parental consent and child assent were obtained according to the guidelines set by the Institutional Review Board, and compliance with local laws related to pediatric clinical trials was ensured.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 6 January 2025 Accepted: 20 March 2025
Published online: 31 March 2025

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