



“Diffusion of innovations”: a feasibility study on the pericapsular nerve group block in the emergency department for hip fractures

Anirudh Ramachandran^{1,5}, Michelle Montenegro¹, Maninder Singh¹, Trevor Dixon¹, Waqas Kayani², Timothy Liang², Nick Yu², Srinivas Reddy³, Anna Liveris³, Mallika Manyapu¹, Alyssia A. McEwan¹, Vincent T. Nguyen¹, Nechama V. Sonenthal^{3,4}, Jill Corbo¹, Benjamin W. Friedman⁵, Jeremy Sperling¹, Michael P. Jones^{1,5}, Michael Halperin¹

¹Department of Emergency Medicine, Jacobi Medical Center, Albert Einstein College of Medicine, Bronx, NY, USA

²Albert Einstein College of Medicine, Bronx, NY, USA

³Department of Surgery, Jacobi Medical Center, Albert Einstein College of Medicine, Bronx, NY, USA

⁴Department of Emergency Medicine, Woodhull Medical Center, Brooklyn, NY, USA

⁵Department of Emergency Medicine, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, NY, USA

Objective Hip fractures are associated with significant morbidity and mortality. Ultrasound-guided peripheral nerve blocks are a safe method to manage pain and decrease opioid usage. The pericapsular nerve group (PENG) block is a novel, potentially superior block because of its motor-sparing effects. Through training, simulation, and supervision, we aim to determine whether it is feasible to perform the PENG block in the emergency department.

Methods Phase 1 consisted of emergency physicians attending a workshop to demonstrate ultrasound proficiency, anatomical understanding, and procedural competency using a low-fidelity model. Phase 2 consisted of a prospective, observational, feasibility study of 10 patients with hip fractures. Pain scores, side effects, and opioid usage data were collected.

Results The median pain score at time 0 (time of block) was 9 (interquartile range [IQR], 6.5–9). The median pain score at 30 minutes was 4 (IQR, 2.0–6.8) and 3.5 (IQR, 1.0–4.8) at 4 hours. All 10 patients required narcotics prior to the initiation of the PENG block with a median dosage of 6.25 morphine milligram equivalents (MME; IQR, 4.25–7.38 MME). After the PENG block, only 30% of the patients required further narcotics with a median dosage of 0 MME (IQR, 0–0.6 MME) until operative fixation.

Conclusion In this feasibility study, PENG blocks were safely administered by trained emergency physicians under supervision. We demonstrated data suggesting a trend of pain relief and decreased opiate requirements, and further investigation is necessary to measure efficacy.

Keywords Nerve block; Hip fractures; Hospital emergency service; Pain management; Interventional ultrasonography

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Correspondence to:

Anirudh Ramachandran
Department of Emergency Medicine,
Jacobi Medical Center, Albert Einstein
College of Medicine, 1400 Pelham
Parkway, Bronx, NY 10461, USA
E-mail: ramachaa2@nychhc.org



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Capsule Summary

What is already known

The pericapsular nerve group block is a novel nerve block described in the literature in 2018. It has the potential to be superior to the other blocks in emergency department patient with hip fractures because of its "motor-sparing" effects.

What is new in the current study

The pericapsular nerve group block is feasible in the emergency department and has the potential to provide excellent pain relief and decrease the amount of opioid use during the preoperative phase in emergency department patient with hip fractures.

INTRODUCTION

Isolated hip fractures are a common presentation to the emergency department (ED) and are associated with significant morbidity and mortality.^{1,2} Regional anesthesia can provide superior pain control when compared to parenteral analgesia and can decrease the need for opioids, avoiding their deleterious side effects of respiratory depression and delirium. Under ultrasound guidance, nerve blocks are a safe, effective method to manage perioperative pain.³⁻⁸ This is a feasibility study of a novel nerve block for hip fractures.

The pericapsular nerve group (PENG) block, described in 2018, is an exciting new analgesic modality that is ideal for the ED management of hip fractures due to its potential for sensory-only nerve blockades.^{2,9} Previously established blocks, such as the femoral nerve block, the "3-in-1" block, and the fascia iliaca block, have shown inconsistent or partial analgesia.⁴ A possible explanation is demonstrated by both magnetic resonance imaging and cadaveric studies illustrating that the obturator nerve (sensory innervation) is rarely affected by these three blocks.¹⁰

The PENG block targets the articular branches of the femoral nerve, accessory obturator nerve, and obturator nerve, which provide sensory-only innervation to the hip.^{2,9,11,12} The articular branches of these three nerves course between the anterior inferior iliac spine (AIIS) and the iliopubic eminence (IPE). By depositing anesthetic anterior to the IPE, the PENG block is able to provide a sensory-only blockade without causing motor weakness.^{2,8,13} The PENG block is potentially more easily adopted than the other blocks because the target for deposition of anesthetic is just anterior to the IPE, which is an easily visualized structure under ultrasound guidance secondary to its density.¹⁴

In an effort to understand and explain the spread of practices and ideas within a population, Everett Rogers published the book

Diffusion of innovations in 1962. Rogers described the phases of innovation adoption and named them early, middle, and late adopters.¹⁴ Early and middle adopters are essential to the success of spreading new practice and ideas. This PENG block project involves recruiting early adopters of this procedure to increase the use of this procedure for our patient population.

Wilson et al.¹⁵ recently attempted to implement the fascia iliaca block and observed significant barriers to changing the practice pattern of emergency physicians (EPs) in the ED. While there is evidence on the efficacy of the fascia iliaca block, they discovered that despite training sessions, attending physicians felt uncomfortable performing the block independently without supervision, and consequently the procedure was not widely adopted. They discovered that it was difficult to persuade the entire staff to adopt this practice since it was seen as a great change within the department's current practice patterns.

Prior to this project, our department was not performing peripheral nerve blocks for hip fractures and introducing the PENG block required a dedicated effort from our ultrasound and simulation divisions. We acknowledged the challenges faced by Wilson et al.¹⁵ specific to hip fracture management in the ED as well as the lessons learned in *Diffusion of innovations* regarding the adoption of new technologies and practice patterns. The PENG block has yet to be studied in an ED population in the United States despite case series and reports internationally showing that the PENG block is highly efficacious for pain.^{2,8,16} With a dedicated 2-hour workshop, including simulation training on a low-fidelity model and direct supervision, we hypothesized that the PENG block can be successfully taught to EPs and is feasible for administration in the ED for providing pain relief and limiting opioid usage. By training early adopters, this would be the first step in the PENG block "diffusion of innovations."

METHODS

Study design

This was a prospective, observational study to test the feasibility of the PENG block for the management of pain. We enrolled 10 cognitively intact patients with hip fractures, all of whom received a PENG block. The subjects were assessed every 10 minutes for the first 30 minutes, then at the 1-, 2-, 4-, 8-, and 16-hour marks after the PENG block. The trial was approved by the Institutional Review Board of the Albert Einstein College of Medicine (No. 2021-12647). All participants provided written consents prior to participation.

Study setting

This study was performed in an academic, urban ED with an annual adult census of approximately 75,000 patients and a mean incidence of 170 hip fractures per year (2016–2020). The center is an American College of Surgeons Designated Adult Level 1 Trauma Center with a large emergency medicine residency training program and an ultrasound and simulation education fellowship. Pain management of hip fractures prior to this study was almost uniformly parenteral analgesia. The study was conducted between January and September 2021.

Study protocol

Phase 1: simulation training (January to April 2021)

EPs attended a 2-hour workshop of lecture and rapid cycle deliberate practice using a low-fidelity model (Supplementary Materials 1, 2, and Supplementary Figs. 1–4). The EPs were required to complete numerous critical actions at three hands-on stations and score higher than 90% on the postworkshop assessment to pass the workshop.

Phase 2: pilot study of 10 patients (July to September 2021)

This was a pilot study assessing the feasibility of EPs to perform PENG blocks on patients. After an initial clinical working assessment by the EPs, the research team was contacted. The EPs provided the analgesia that they deemed appropriate while radiographs were obtained and consultants were contacted. After radiographic confirmation and patient consent, the PENG block was administered by EPs under direct supervision of the research team. The amount of time from needle entry to final needle exit from the skin was recorded.

Recruitment

Patients were eligible for the study if they were cognitively intact (alert and oriented to person, place, and time), had a radiographi-

cally confirmed hip fracture, had a pain score of at least 5 out of 10 at triage or upon EP evaluation, and were able to indicate their pain score on a visual analog pain scale which ranged from 0 (no pain) to 10 (severe pain). Patients were excluded in cases of multi-trauma.

Materials and PENG block placement

The 10 PENG blocks were performed under ultrasound guidance with a curvilinear transducer (Sonosite XPorte 5–2 MHz; FUJIFILM SonoSite, Bothell, WA, USA) utilizing a 22-gauge 3.5- or 4-inch PaJunk SonoBlock II (Pajunk Medical Systems, Alpharetta, GA, USA) echogenic needle under sterile techniques. A block kit was developed which contained all the required materials for the procedure (Fig. 1). This kit was prepackaged for convenience and included syringes, sterile gloves, needles, sterile towels, an ultrasound probe cover, and chlorhexidine swabs. Anesthetic was obtained from the ED medication distribution system. The ultrasound machine along with the kit was brought into the room prior to the start of the procedure. The preparation time was typically less than 2 minutes.

Patient positioning is key to ensure a successful block. The physician stood on the ipsilateral side of the hip fracture with the ultrasound machine placed on the opposite side to ensure a direct line of sight of the procedural field and ultrasound screen.

The patient was placed on a cardiac monitor with continuous pulse oximetry. A preprocedural time out was called and vital signs were recorded. A bladder ultrasound was completed, and if gross-



Fig. 1. Block kit materials.

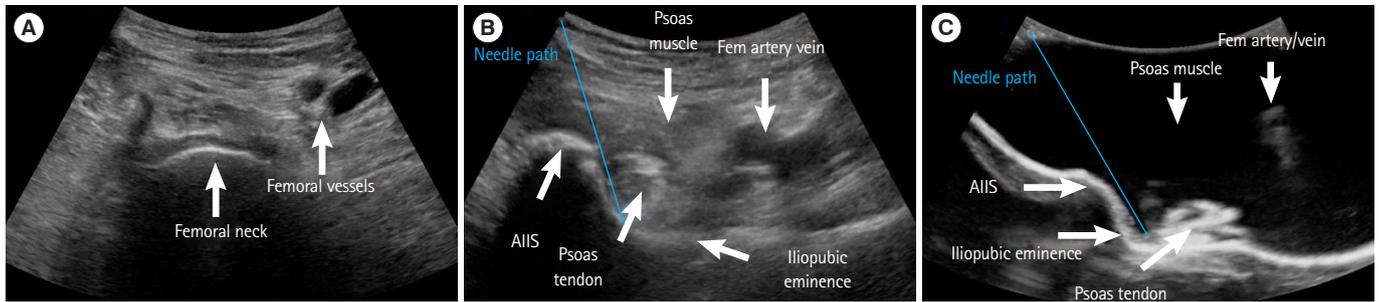


Fig. 2. Patient versus low-fidelity pericapsular nerve group (PENG) block model. (A) Anatomical view in a patient of the characteristic femoral neck (image left is lateral and image right is medial). (B) Anatomical view of the right hip in a patient (image left is lateral and image right is medial). The white arrows illustrate the key anatomical landmarks and the blue line indicates the ideal needle trajectory during a PENG block. (C) Anatomical view of the right hip on our low-fidelity PENG block model (image left is lateral and image right is medial). The white arrows illustrate the key anatomical landmarks and the blue line indicates the ideal needle trajectory during a PENG block. AIIIS, anterior inferior iliac spine.

ly distended, a urinary catheter was placed to decompress the bladder. Operator 1 prepped the patient's skin under aseptic technique and a sterile ultrasound cover was placed on the curvilinear transducer. Since the femoral neck has an identifiable semi-circular shape, the transducer was aligned with the inguinal crease searching for this image (Fig. 2). The femoral artery and vein were identified medially and care was taken to avoid these structures. Once this image was obtained, the transducer was moved slightly superiorly to identify the IPE (Fig. 2). The IPE and psoas tendons were identified and a skin wheal was introduced at the needle insertion site. The echogenic nerve block needle was flushed with normal saline. Sterile operator 1 introduced the needle from lateral to medial using an in-plane approach, placing the tip of the needle in the musculofascial plane inferior to the psoas tendon and superior to the IPE. Once the operator contacted the IPE, the needle was rotated to ensure that the fascial layer lying above the bone was pierced. Operator 2 hydrodissected the area with normal saline (injected in 5 mL aliquots) to verify vertical rise of the psoas tendon off of the IPE, ensuring appropriate placement of the needle. Once both operators were satisfied with the needle placement, bupivacaine 0.25% was delivered slowly up to the planned dose of 20 mL. After the administration of bupivacaine, normal saline was once again flushed (3–4 mL) to empty the anesthetic left in the tubing and the needle. Postprocedural vital signs were recorded.

Phase 1 methods

Our ultrasound and simulation fellowship faculty developed a 2-hour workshop, incorporating a preworkshop questionnaire, a brief lecture with key images, three hands-on stations, and concluded with a postassessment questionnaire to assess for knowledge acquisition. To conduct this workshop in an efficient and timely manner, we required four facilitators, a computer, an ul-

trasound machine, low-fidelity PENG models, echogenic ultrasound needles, and sterile equipment. The questionnaire focused on anatomy, indications, contraindications, terminology, and included questions regarding comfort levels.

The 20-minute lecture at the beginning of the workshop addressed the background regarding the PENG block and described the PENG block as an anatomically derived nerve block targeting the articular branches of the femoral nerve, obturator nerve, and accessory obturator nerve as they course over the IPE and innervate the sensory receptors located in the anterior zone of the hip. It also discussed the indications, contraindications, complications, local anesthetic systemic toxicity treatment, and detailed a step-by-step approach to the PENG block using a two-person technique.

Station 1

The first station focused on informed consent using a standardized patient. A trained facilitator played the role of the patient and ensured that each participant was able to address the following critical actions: confirm the patient's name, date of birth, side of injury, describe the procedure in its entirety to the patient, discuss risk and benefits, search for contraindications, ask the patient if they have questions, and finally determine if the patient is able to provide consent. The facilitator running the station determined the standardized patient's history and ability to consent based on the facilitator's discretion. The participant needed to complete all critical actions to pass this station.

Station 2

The second station focused on visualizing the needle tip in its entirety using an in-plane ultrasound approach. The participants in this station practiced this skill by identifying a target on a low-fidelity model. The critical actions required at this station included:

describing the needle trajectory prior to insertion, identifying the needle tip upon entry into the "skin," readjusting the ultrasound if the needle tip was not identified, demonstrating visualization of the entire shaft of the needle throughout procedure, and accurately reaching an identified target. The participant needed to complete all critical actions to pass this station.

Station 3

The third station focused on the translation of knowledge using hands-on experience on the low-fidelity PENG model through rapid cycle deliberate practice and incorporated technical ultrasound skills, image acquisition, and ability of the operator to follow their needle tip. The participant was tasked with choosing the correct transducer (curvilinear) and adjusting for depth and gain appropriately. The participant needed to correctly match the side of the transducer to the corresponding orientation on the ultrasound screen and identify the AIIIS, psoas muscle, psoas tendon, IPE, and femoral neurovascular bundle.

The facilitator verified that the participant was able to track the needle for the entirety of the approach with the in-plane method. The participant needed to avoid hitting the AIIIS and avoid going through the psoas tendon. Fig. 2 depicts the ideal path using the blue line. The participant needed to verbalize several key actions at this station: aseptic procedure set-up (hand-washing, sterile gloves, probe cover, drawing up anesthetic, and sterile field placement), lidocaine wheal placement, a description of what a successful block means (psoas tendon rise with the underlying local anesthetic), and anesthetic placement in 5 mL increments. While our model did not support the physical injection of fluids, the participants were advised ahead of time the necessity of verbalizing this step as a part of the critical actions.

Anchoring one's transducer hand on the model is important to ensure the stability of the transducer and desired image. It is also important to anchor the needle hand to help guide it through the desired trajectory. The participants were judged on their overall stability/probe technique during the procedure on a scale from 0 to 2, with the lowest score (0) indicating no stability and the highest score (2) indicating excellent stability.

To pass this station, the participants needed to hit all the critical actions listed above and score a stability score of 1 or higher. The participants were required to repeat each station if they did not pass the first time, but the number of attempts was not recorded.

Measurements

For phase 1, the average scores on the preworkshop and postworkshop assessments were obtained. Comfort levels on a Likert

scale were obtained in the preworkshop and postworkshop as well. For phase 2, pain scores were collected at predetermined time intervals: triage, 0, 10, 20, and 30 minutes, 1, 2, 4, 8, and 16 hours. The 0-minute time was immediately before the block was initiated and all the subsequent times were based on the time of completion of the PENG block. The EPs and inpatient physicians all had the option to treat the patient preblock or postblock with their choice of pain regimen if they felt that it was clinically warranted. Side effects and the amount of opioids provided were monitored until the patient went to the operating room. In addition, the time from triage to block and triage to operating room was recorded. Needle entry to exit times were also recorded based on time-stamps obtained during image review.

Data analysis

The sample size was set at 10 patients for a pilot feasibility study. Data was compiled using a standard spreadsheet application (Excel; Microsoft, Redmond, WA, USA) and analyzed using IBM SPSS ver. 22.0 (IBM Corp., Armonk, NY, USA). The normality of the data was evaluated using the Kolmogorov-Smirnov test. Normally distributed continuous data were presented as mean and standard deviations, and nonparametric data were presented as a median with interquartile ranges. Categorical data were summarized in cross-tab, expressed as percentages of the group with 95% confidence interval (CI), and analyzed using the chi-square test. For all analyzed data, statistical significance was set at a P-value of <0.05.

RESULTS

Overall, 21 attending physicians and five residents attended and completed the workshop in phase 1. Identical preworkshop and postworkshop assessments were provided to each participant. The average score on the preworkshop assessment was 61% and the average postworkshop assessment score was 95%, a difference of 34% (95% CI, 11.6–53.4; $P=0.003$). Comfort levels before the workshop went from 2.4 out of 5 to 4 out of 5 for a difference of 1.6 (95% CI, 0.3–2.6; $P=0.02$) (Fig. 3).

Table 1 illustrates the demographics of the patients enrolled in phase 2 of the study. There were 10 cognitively intact patients, six females and four males. The median age was 80.5 years (interquartile range [IQR], 72.5–84.5 years). Seventy percent of the hip fractures were intertrochanteric, while 30% involved the femoral neck. Three blocks were performed by senior residents, four blocks by nonultrasound fellowship-trained attendings, and three by ultrasound fellowship-trained attendings. Overall, nine different EPs performed the 10 blocks with one person administering two. The mean time from needle entry to final needle exit

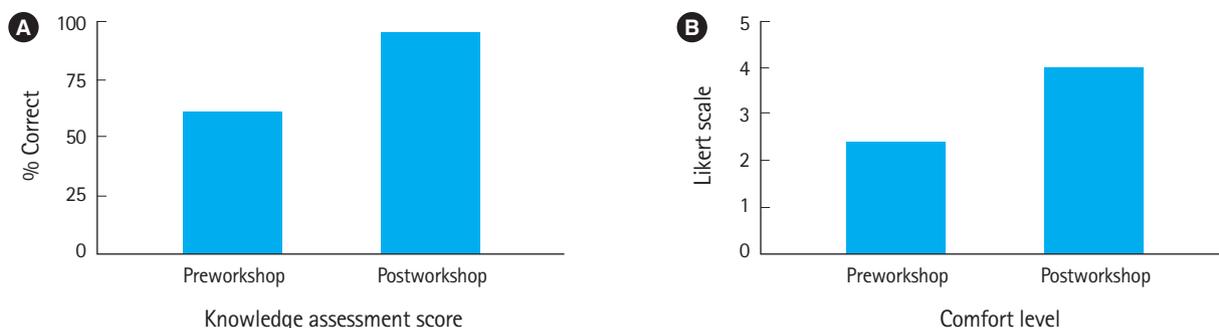


Fig. 3. Average preworkshop and postworkshop (A) assessment scores for all the participants and (B) comfort levels on a Likert scale (1, very uncomfortable; 2, uncomfortable; 3, neutral; 4, comfortable; and 5, very comfortable).

Table 1. Patient demographics and procedural data

Patient no.	Age (yr)	Sex	Fracture type	Preblock MME	Postblock MME	Time to PENG block	Time to OR	Operator	Needle entry to exit
1	101	Female	Left IT	9.0	0	4 hr 10 min	20 hr 44 min	PGY-3	19 min
2	83	Female	Right Fem Neck	11.5	0	3 hr 5 min	20 hr 3 min	PGY-4	36 min
3	59	Female	Left IT	5.0	5.0	1 hr 45 min	27 hr 30 min	Non-US fellowship-trained attending	21 min
4	95	Male	Left Fem Neck	7.0	0	8 hr 11 min	20 hr 1 min	US fellowship-trained attending	15 min
5	74	Female	Left IT	7.5	0	7 hr 28 min	42 hr 30 min	US fellowship-trained attending	20 min
6	63	Male	Left IT	6.5	0	3 hr 40 min	25 hr 44 min	US fellowship-trained attending	16 min
7	94	Male	Right Fem Neck	6.0	0.8	7 hr 41 min	39 hr 9 min	Non-US fellowship-trained attending	17 min
8	83	Female	Right IT	4.0	0	1 hr 55 min	32 hr 15 min	Non-US fellowship-trained attending	12 min
9	78	Male	Left IT	4.0	0	4 hr 45 min	13 hr 57 min	PGY-3	19 min
10	72	Female	Left IT	4.0	4.0	1 hr 27 min	18 hr 17 min	Non-US fellowship-trained attending	15 min

The following conversion scale was used: fentanyl 10 μ g = 1 MME, oxycodone 1 mg = 1.5 MME, and hydromorphone 1 mg = 4 MME.

MME, morphine milligram equivalents; PENG, pericapsular nerve group; OR, operating room; IT, intertrochanteric fracture; PGY, postgraduate year; Fem Neck, femoral neck fracture; US, ultrasound.

was 19 minutes. All of the physicians who performed the block had attended the workshop and reported that practicing on the model increased their comfort level prior to performing the block on a live patient.

The median pain score at the time of the patient being triaged was 10 (IQR, 0–10). All 10 patients (100%) required an opioid (oxycodone/acetaminophen, morphine, or fentanyl) prior to the initiation of the PENG block with a median dosage of 6.25 morphine milligram equivalents (MME; IQR, 4.25–7.38 MME). After the PENG block, only 30% of the patients required further narcotic dosing until operative fixation with a median dosage of 0 MME (IQR, 0–0.6 MME).

Fig. 4 illustrates the median pain score of all 10 patients at each time interval. The median door to block time was 3 hours 55 minutes (IQR, 2 hours 13 minutes to 6 hours 47 minutes). The median pain score at time 0 (time of block) was 9 (IQR, 6.5–9.0) out of 10. At 30 minutes, the median pain score was reduced to 4.0 (IQR, 2.0–6.8) with a further reduction to 3.5 (IQR, 1.0–4.8) at the 4-hour mark. Data was not obtained for the 960-minute time

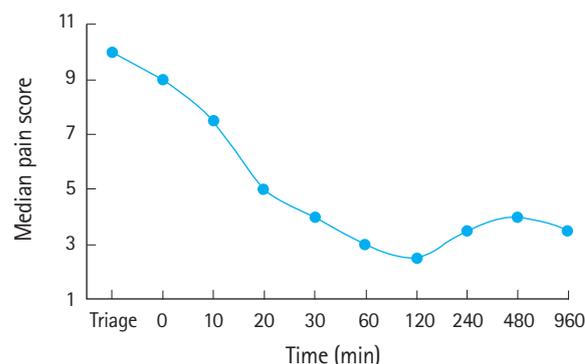


Fig. 4. Pericapsular nerve group block median pain scores. Median pain scores for all participants at the respective time interval.

point in six patients. Seven patients received no opioids after the block was placed, while three required breakthrough opioid analgesia. Fig. 5 illustrates preblock and postblock opioids. One patient received 0.2 mg hydromorphone (5 hours 45 minutes after the block), one patient received 4 mg of morphine (1 hour 25 minutes after the block), and one patient received 50 μ g of fentanyl

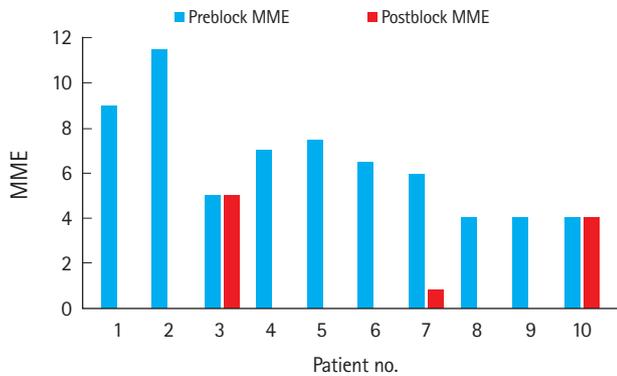


Fig. 5. The prepericapsular and postpericapsular nerve group block morphine milligram equivalents (MME) for all patients. The following conversion scale was used: fentanyl 10 μg = 1 MME, oxycodone 1 mg = 1.5 MME, and hydromorphone 1 mg = 4 MME.

(10 minutes after the block) along with 30 mg methadone, which was the patient's home maintenance dose. Since the patient's methadone was their home dose, it was not included in the post-block MME calculation. The following conversion scale was used: fentanyl 10 μg = 1 MME, oxycodone 1 mg = 1.5 MME, and hydromorphone 1 mg = 4 MME. Overall, minimal opioids were used between the time of the block and the time the patient went to the operating room with a median time of 23 hours 14 minutes (IQR, 20 hours 2 minutes to 31 hours 4 minutes).

There were no procedural complications and no side effects reported from the block. All ultrasound images during the procedure were archived in our institution's image archival system and analyzed for quality assurance.

DISCUSSION

In an ED practice environment where the standard of care is parenteral analgesia for hip fractures, our objective was to determine if we could successfully teach and perform the PENG block through training, simulation, and supervision to a group of early adopters. The PENG block was chosen for three primary reasons: its motor function sparing effects, the simplicity of the anatomical landmarks for the deposition of anesthetic, and the safe distance between the target and the femoral vascular bundle. Our long-term goal is to train middle and late adopters and further study the effectiveness of the PENG block for decreasing pain and reducing opioid usage.

We received overwhelmingly positive feedback regarding our simulation training workshop. The participants enjoyed the template of our workshop, having the opportunity to practice on a model with striking anatomical similarities. We noticed that the EPs who practiced and mastered the in-plane needling technique

were quickly able to transfer this technique to live patients. The biggest role of supervision during these 10 live patients was to help with image acquisition. Our experience was that once the EPs could obtain an image similar to the low-fidelity model they trained on, they were comfortable completing the rest of the steps of the procedure. The key factors that influenced how long the procedure took were the time to adequate image acquisition and the skill of the in-plane technique. As an example, in patient 2, it took longer for the proceduralist to complete the block, secondary to issues tracking the needle in-plane that required adjustments.

EPs treated the patient's pain with parenteral or oral analgesics of their choice. For the block, bupivacaine was chosen due to its safety, availability, and long-lasting analgesia. For future studies, we will consider a mixture of lidocaine and bupivacaine so that patients can potentially benefit from the quicker onset of analgesia.

Patient 3 and patient 10 appeared to be outliers as the pre-block and postblock morphine equivalents were the same. During quality assurance, we noticed suboptimal images of the needle tip during insertion, but postblock images illustrated an anechoic fluid collection underneath the psoas muscle in both patients. Postblock medications involved fentanyl 50 μg provided 10 minutes after the block for patient 3 and morphine 4 mg administered 1.5 hours after the block for patient 10. The pain scores of patient 3 and patient 10 continued to decrease and required no further opioid use until after surgery. We hypothesize that the patient's block did not necessarily fail, but that its onset was not rapid enough. We theorize that if a mixture of lidocaine and bupivacaine was used, it may have provided quicker onset of pain relief than just bupivacaine alone and suggest that as one future area of further study.

Another challenge in our study had to do with the subjectivity of the pain scores. At the 1-hour mark, six patients had a pain score of less than 4, while four patients reported a score greater than 6. In a few of our patients after the PENG block was administered, we observed that they were seated at a 35° to 40° incline, appeared comfortable as they ate or conversed with family members, and declined additional pain medications, but still reported a pain score greater than 6. While we believe pain scores are helpful, we included postblock opioid consumption data in relation to the time to operative fixation as an objective surrogate measurement to determine if the block was successful or not. Future studies can also look at the amount of additional doses needed as criteria as well.

With proper training, simulation, and supervision, it is feasible for senior residents, ultrasound fellowship-trained faculty, and non-fellowship-trained faculty to perform the PENG block. There

is promising potential to decrease opioid use while providing pain relief in patients with hip fractures. A follow-up with a randomized, controlled study with a larger sample size is potentially needed to confirm the efficacy of the PENG block.

A potentially larger challenge lies ahead in the adoption of a new innovation. It has been 60 years since Everett Rogers first published *Diffusion of innovations* in 1962,¹⁴ and we now have a core group of nearly a dozen early adopter EPs who are able to administer a PENG block. In order to expand the use of the PENG block in our department, we believe that a PENG block on-call team to provide assistance and supervision could be helpful. The on-call team's availability for a year or two would offer a longitudinal program that captures the middle and late adopters, increasing the likelihood of adoption of the PENG block in everyday practice in the ED.

This study is limited by a small sample size and the lack of a control group. It is also a convenience sample given the availability of the research team, which may have introduced selection bias. Pain score collection was a combined effort among the research team and its medical students, but pain scores were sometimes collected by the same person who performed the block, which could potentially add bias. We did not keep records of which person collected the individual scores for each patient. Another limitation was a failure to record the number of attempts required for the needle to reach its target.

The results of this study suggest that it is possible for EPs to safely perform the PENG block in the ED for patients with hip fractures after simulation training and initially under supervision. The PENG block provides pain relief while decreasing the use of opioids for patients with hip fractures in the ED.

SUPPLEMENTARY MATERIAL

Supplementary Material 1. Low-fidelity model

Supplementary Material 2. Pericapsular nerve group (PENG) block knowledge assessment

Supplementary Fig. 1. Plastic pelvis model in 15-L plastic bin, low-fidelity pericapsular nerve group (PENG) simulator.

Supplementary Fig. 2. Foamy layer on top after gelatin mixed, low-fidelity pericapsular nerve group (PENG) simulator.

Supplementary Fig. 3. Yarn and gel filled straws represent tendon and vessels respectively, low-fidelity pericapsular nerve group (PENG) simulator.

Supplementary Fig. 4. Final product low-fidelity pericapsular nerve group (PENG) simulator.

Supplementary materials are available at <https://doi.org/10.15441/ceem.22.177>.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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ORCID

Anirudh Ramachandran	https://orcid.org/0000-0002-3767-9948
Michelle Montenegro	https://orcid.org/0000-0002-8982-609X
Maninder Singh	https://orcid.org/0000-0001-7784-0751
Trevor Dixon	https://orcid.org/0000-0002-9714-5219
Waqas Kayani	https://orcid.org/0000-0002-2011-9194
Timothy Liang	https://orcid.org/0000-0002-1641-2566
Nick Yu	https://orcid.org/0000-0002-2677-8318
Srinivas Reddy	https://orcid.org/0000-0003-3369-5745
Anna Liveris	https://orcid.org/0000-0003-4386-4207
Mallika Manyapu	https://orcid.org/0000-0003-0595-6530
Alyssia A. McEwan	https://orcid.org/0000-0001-6342-2524
Vincent T. Nguyen	https://orcid.org/0000-0002-6736-1279
Nechama V. Sonenthal	https://orcid.org/0000-0002-4924-5645
Jill Corbo	https://orcid.org/0000-0001-8153-5709
Benjamin W. Friedman	https://orcid.org/0000-0002-2753-5860
Jeremy Sperring	https://orcid.org/0000-0002-6932-8536
Michael P. Jones	https://orcid.org/0000-0001-8500-4075
Michael Halperin	https://orcid.org/0000-0003-2361-5932

REFERENCES

1. Brauer CA, Coca-Perrillon M, Cutler DM, Rosen AB. Incidence and mortality of hip fractures in the United States. *JAMA* 2009; 302:1573-9.
2. Giron-Arango L, Peng PW, Chin KJ, Brull R, Perlas A. Pericapsular nerve group (PENG) block for hip fracture. *Reg Anesth Pain Med* 2018;43:859-63.

3. Beaudoin FL, Nagdev A, Merchant RC, Becker BM. Ultrasound-guided femoral nerve blocks in elderly patients with hip fractures. *Am J Emerg Med* 2010;28:76-81.
4. Beaudoin FL, Haran JP, Liebmann O. A comparison of ultrasound-guided three-in-one femoral nerve block versus parenteral opioids alone for analgesia in emergency department patients with hip fractures: a randomized controlled trial. *Acad Emerg Med* 2013;20:584-91.
5. Turner AL, Stevenson MD, Cross KP. Impact of ultrasound-guided femoral nerve blocks in the pediatric emergency department. *Pediatr Emerg Care* 2014;30:227-9.
6. Guay J, Parker MJ, Griffiths R, Kopp S. Peripheral nerve blocks for hip fractures. *Cochrane Database Syst Rev* 2017;5:CD001159.
7. Ma YH, Wu J, Jia B, Xue JX, Wang TL. Continuous fascia iliaca compartment block combined with oral analgesics for pre-operative pain control in elderly hip fracture patients. *Zhonghua Yi Xue Za Zhi* 2018;98:723-7.
8. Acharya U, Lamsal R. Pericapsular nerve group block: an excellent option for analgesia for positional pain in hip fractures. *Case Rep Anesthesiol* 2020;2020:1830136.
9. Gerhardt M, Johnson K, Atkinson R, et al. Characterisation and classification of the neural anatomy in the human hip joint. *Hip Int* 2012;22:75-81.
10. Marhofer P, Nasel C, Sitzwohl C, Kapral S. Magnetic resonance imaging of the distribution of local anesthetic during the three-in-one block. *Anesth Analg* 2000;90:119-24.
11. Birnbaum K, Prescher A, Hessler S, Heller KD. The sensory innervation of the hip joint: an anatomical study. *Surg Radiol Anat* 1997;19:371-5.
12. Gofeld M. Pericapsular nerve group (PENG) block: an ethical and academic perspective. *Reg Anesth Pain Med* 2019;44:904-5.
13. Berlioz BE, Bojaxhi E. PENG regional block. Treasure Island, FL: StatPearls Publishing; 2021
14. Rogers EM. Diffusion of innovations. 1st ed. New York, NY: Free Press of Glencoe; 1962.
15. Wilson J, Maloney K, Bookman K, et al. Training emergency physicians in ultrasound-guided fascia iliaca compartment blocks: lessons in change management. *Cureus* 2019;11:e4773.
16. Jadon A, Sinha N, Chakraborty S, Singh B, Agrawal A. Pericapsular nerve group (PENG) block: a feasibility study of landmark based technique. *Indian J Anaesth* 2020;64:710-3.

Supplementary Material 1. Low-fidelity model

As far as we know, there are no commercially available high-fidelity or low-fidelity models for the pericapsular nerve group (PENG) block. Our low-fidelity model underwent multiple iterations. We described our method for creating this model below and hope that it will be useful for others.

Multiple studies describe the effectiveness of low-fidelity models in helping emergency physicians simulate ultrasound guided procedures. Tendons and nerves can be mimicked by yarn soaked in ultrasound gel. Vessels can be mimicked by straws filled with ultrasound gel. Lastly, ballistic gel serves as an excellent medium for ultrasound and has been used to create various different simulators.

To build our low-fidelity PENG simulator, we purchased the following: a plastic skeletal pelvis model (Amazon, Seattle, WA, USA; \$35.96) as illustrated in Supplementary Fig. 1, a 15-L clear plastic bin (Home Depot, Atlanta, GA, USA; \$4.97), 2 lbs of Knox gelatin powder (Amazon, \$20.37), and a Hamilton Beach 6-Speed open handle hand mixer (Target, Minneapolis, MN, USA; \$27.26).

The goal was to encapsulate the pelvis in gelatin while simultaneously ensuring the yarn and straws are suspended in the appropriate anatomical locations. We proceeded with a two-layer technique. We used tape to secure the pelvis to the bottom of the bin. We mixed 9 L of boiling hot water with 24 ounces of Knox gelatin to create the first layer. We used multiple pots and a water kettle to bring tap water to a boil and pour it into the bin. We introduced 2.6 ounces of gelatin for every liter of water utilizing the hand mixer to reduce clumping. It is important to make sure there is immediate mixing of the gelatin powder to avoid clumping. We recommend an electronic hand mixer to ensure the gelatin is equally mixed throughout the bin. Once all 9 L are in, there will be a foamy layer on top illustrated in Supplementary Fig. 2. We used a spoon to slowly scoop out the foam and any remaining clumps. The model needs to be left in the refrigerator for a minimum of 6 to 8 hours but we opted to leave it in the refrigerator overnight.

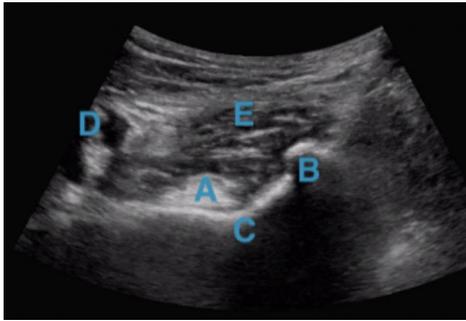
Once sufficient time has passed, the gelatin will harden and you may notice air bubbles at the top. You can use a spoon or a knife to remove any air bubbles that may have risen to the surface. With a knife, make an incision over the iliopubic eminence, cut a small piece of yarn soaked in ultrasound gel and place it on both sides. Use plastic straws filled with ultrasound gel and place just lateral to the pubic symphysis. Ensure that there is no air inside the straw and cut the straw if needed to the desired length. At this point, you may use the space around the pelvis and place small pieces of yarn to serve as target practice for the in-plane approach. Supplementary Fig. 3 illustrates the yarn and straws in their appropriate places.

Lastly, boil 3 to 4 L of water and mix in Knox gelatin powder using the electronic hand mixer in a separate pot. Slowly introduce the pre-mixed solution into the bin so as to not disturb the yarn and straws until the entire pelvis is covered. Place it back in the fridge for 4 to 6 hours and the model is ready for use. Please note that in this initial model, we did not place pieces of yarn around the pelvis to serve as target practice, but after an iterative feedback process, we did for the second model we made. Supplementary Fig. 4 demonstrates the final product.

We added a thin layer of water on top of the model to prevent ultrasound gel requirement during the training session. We found that the thin water layer greatly diminished the artifacts left over by the needle in between learners as an added benefit.

Once the model was used for a session, we were able to refrigerate the model for several weeks. Prior to the next session, only the top layer was cut out and a new layer was added and the model was ready to be reused. Roughly 1 L of water and 3 ounces of gelatin were used to replace the top layer. This model lasted through multiple sessions over 10 weeks. At each session, the model underwent well over 100 needle sticks without leaving any significant leftover artifact.

Supplementary Material 2. Pericapsular nerve group (PENG) block knowledge assessment



1. Match the following anatomical landmarks on the figure with the appropriate letter (each one point)
 - 1) Iliopsoas muscle
 - 2) Psoas minor tendon
 - 3) IPE (iliopubic eminence)
 - 4) Femoral neurovascular bundle
 - 5) AIIS (anterior inferior iliac spine)

2. Which of the following is true about the PENG block?
 - 1) Provides a sensory only blockade
 - 2) Described in 2018
 - 3) Deposits anesthetic superior to the iliopubic eminence
 - 4) Both A and C
 - 5) All of the above

3. What complications do patients with hip fractures face?
 - 1) Untreated pain
 - 2) Pneumonia
 - 3) Delirium
 - 4) All of the above
 - 5) None of the above

4. Which part of the hip joint provides the most sensory information to the brain (i.e., pain)?
 - 1) Anterior
 - 2) Posterior
 - 3) Medial
 - 4) Lateral

5. Which of the following nerves provide the majority of pain sensation from the hip joint?
 - 1) Sciatica nerve
 - 2) Femoral nerve
 - 3) Obturator nerve
 - 4) All of the above
 - 5) B and C only

6. What landmark should you palpate to help aid image acquisition?
 - 1) Anterior superior iliac spine
 - 2) Anterior inferior iliac spine
 - 3) Pubic symphysis
 - 4) Greater trochanter

7. What indicates a successful PENG block?
 - 1) Lateral displacement of psoas tendon on the ultrasound screen
 - 2) Medial displacement of psoas tendon on the ultrasound screen
 - 3) Anterior/superior displacement of psoas tendon on the ultrasound screen

8. Where is intralipid located in the ED (emergency department)?
 - 1) Resus bay Pyxis
 - 2) Pharmacy
 - 3) Above the lidocaine inside medication room
 - 4) North side of ED

9. What are the first signs and symptoms of LAST (local anesthetic systemic toxicity)?
 - 1) Tongue/lip paresthesias
 - 2) Tinnitus
 - 3) Coma
 - 4) Only A and B
 - 5) All of the above

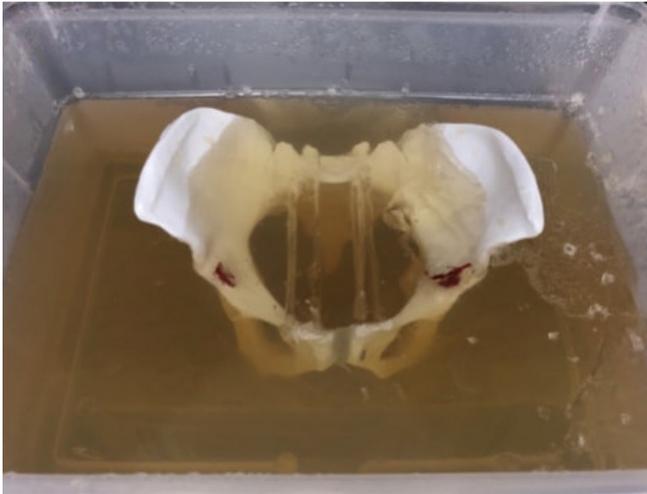
10. What are contraindications to the PENG block?
 - 1) Patient refusal
 - 2) Allergy to anesthetic
 - 3) Infection over injection site
 - 4) Multi-system trauma
 - 5) All of the above



Supplementary Fig. 1. Plastic pelvis model in 15-L plastic bin, low-fidelity pericapsular nerve group (PENG) simulator.



Supplementary Fig. 2. Foamy layer on top after gelatin mixed, low-fidelity pericapsular nerve group (PENG) simulator.



Supplementary Fig. 3. Yarn and gel filled straws represent tendon and vessels respectively, low-fidelity pericapsular nerve group (PENG) simulator.



Supplementary Fig. 4. Final product low-fidelity pericapsular nerve group (PENG) simulator.