A randomized, controlled simulation study comparing single and double operator ultrasound-guided regional nerve block techniques using a gelatine-based home-made phantom

Betül Güven Aytaç, MD[a] (iD), Şeyma Ünal, MD, İsmail Aytaç, MD

Abstract

Background: The aim of this study was to compare anesthesiology residents' acquisition of gripping and needling skills in either single-or double-operator ultrasound-guided nerve block using a hand-made phantom.

Design: Prospective, randomized controlled study.

Methods: After a tutorial session, 47 ultrasound-novice residents performed needling with double and single operator (Jedi, Bedforth, On-lock) grip techniques in each of the 3 interventional task sessions.

Results: The time to perform the correct grip and needling decreased significantly between sessions for each technique ($P < .001$). While the double operator tasks required a shorter time than the single operator tasks in all 3 sessions ($P < .001$), there was no significant difference between the single-operator techniques. The number of needling attempts was similar between techniques and sessions. Participants rated the workload higher for the single-operator techniques on the National Aeronautics and Space Administration Task Load Index.

Conclusion: Hands-on training of phantom models may be beneficial for the acquisition of single-operator grip skills.

Abbreviations: Adj. Sig. = adjusted p, ASRA-ESRA = The American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anesthesia and Pain Therapy, Max = Maximum, Min. = minimum, NASA-TLX = National Aeronautics and Space Administration Task Load Index, SD = standard deviation, USG = Ultrasound

Keywords: Anesthesiology training, Bedforth grip, home-made phantom model, Jedi Grip, On-lock grip, single-operator ultrasound-guided regional nerve block.

1. Introduction

Ultrasound (USG) guided peripheral nerve block is commonly performed using a double-operator grip technique. The first operator uses 1 hand to control the USG probe and the other hand to position the needle tip. Meanwhile, the second operator ("assistant") aspirated the syringe to check whether the needle tip was inside the vascular structure. If the result was negative, the assistant delivered a local anesthetic solution.

By contrast, a single operator may manipulate the USG probe, needle, and syringe. Several of these single-operator grip techniques have been described.[1–4] These techniques may obviate some of the deficiencies of the double operator technique, such as the lack of tactile feedback of injection pressure and the requirement of communication and coordination between the operator and assistant.[1–6] The frequency of the use of these single-operator grip techniques in clinical practice is uncertain.[1–4]

Structured education on single-operator grip techniques is not common in anesthesia residency programs. Hands-on training of regional anesthesia in phantom models may provide a suitable environment to acquire and apply the skills required for procedures using USG without risking the health and safety of patients.[7,8]

The aim of this prospective randomized controlled study was to compare the performance of anesthesia residents with double-operator USG-guided peripheral nerve block techniques with that of 3 single-operator techniques: Jedi,[1] On-lock,[2] and Bedforth[3] in 3 practice sessions on a home-made gelatine-based phantom model after a one-to-one tutorial session.

The main objective outcomes of the study were time to correct grip, number of attempts until correct needling, and needling time to position the needle tip to the target area for each technique and session. Residents also subjectively assessed the workload of the single and double operator grip techniques with the National Aeronautics and Space Administration Task Load Index (NASA-TLX)[9] and the benefit of education by using a phantom.

2. Methods

This study was approved by the Ankara City Hospital Human Research Ethics Committee (approval number: E1-20-804 on 11/06/2020) and registered at ClinicalTrials.gov (date: July 27, 2020; ID: NCT04487366). This prospective, randomized controlled study was conducted between July and October 2020 at Ankara City Hospital.
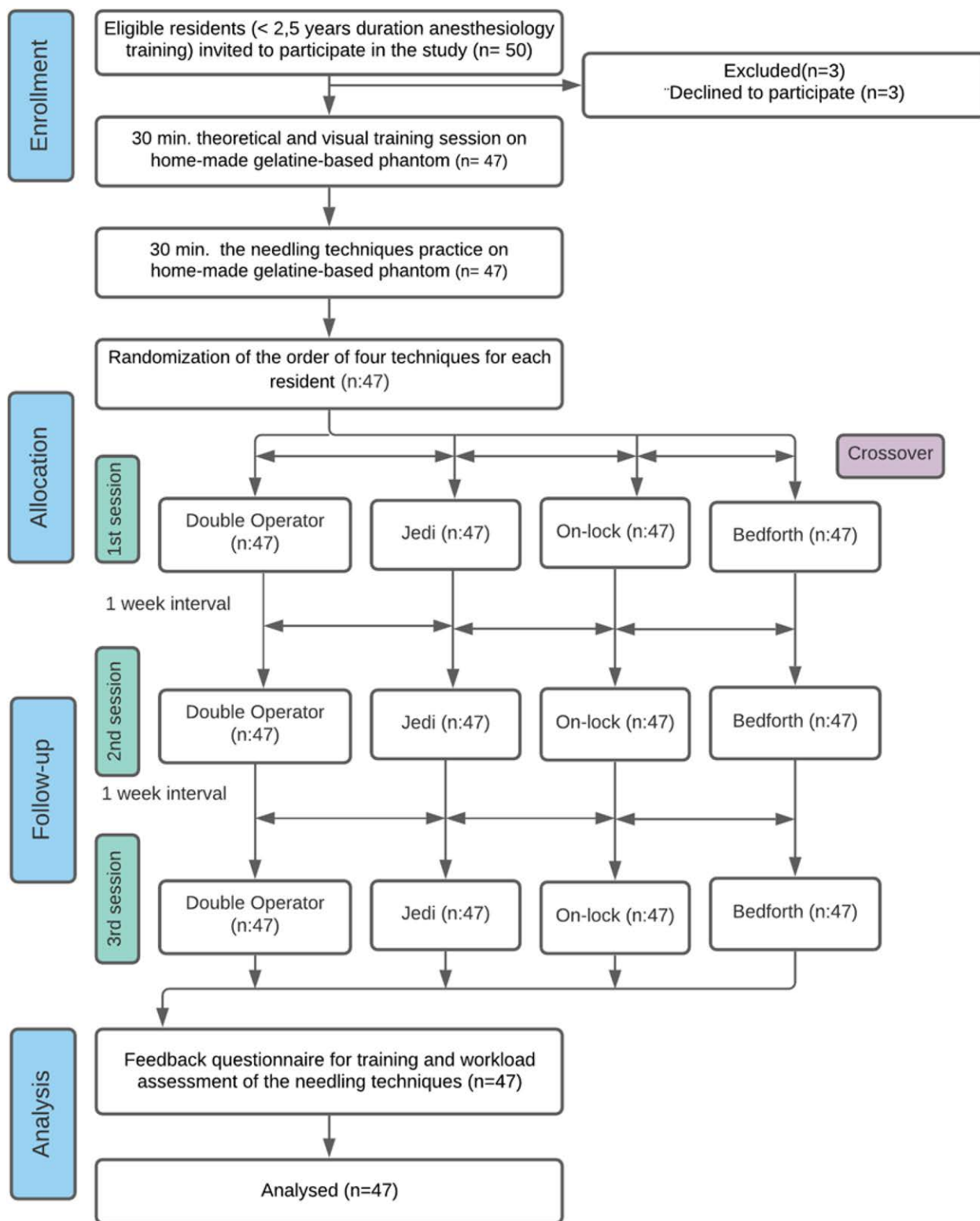

Figure 1. Flow diagram of the study.

2.1. Production of home-made gelatine based phantom

Four quadrangular aluminum cake molds [23 × 8 × 6 cm (length × width × height)] were pierced in the middle of the short sides, and a soft plastic hose (external diameter of 1 cm and internal diameter of 0,5 cm) was passed through them. The gaps in the holes were filled by applying cold silicone around the hose to prevent fluid leakage. Powder gelatin (500 g) and dark blue dye (2 g) in hot water (1800 ml of hot water were mixed using an electric mixer.[10] The solution was poured into a cake mold. Air bubbles on the surface were removed using a spoon prior to solidification. The invisible soft plastic hose passing through the middle of the phantom model created a hyperechoic target area on the USG. Throughout the study, a total of 32 phantoms were produced 8 times to provide a previously unused field on the phantom for residents and to minimize prior needle tracks in each session. The researcher assessed the degree of phantom wear and changed it if it was worn. The number of times the phantom could be used varied for each phantom. The phantoms were stored in a refrigerator.
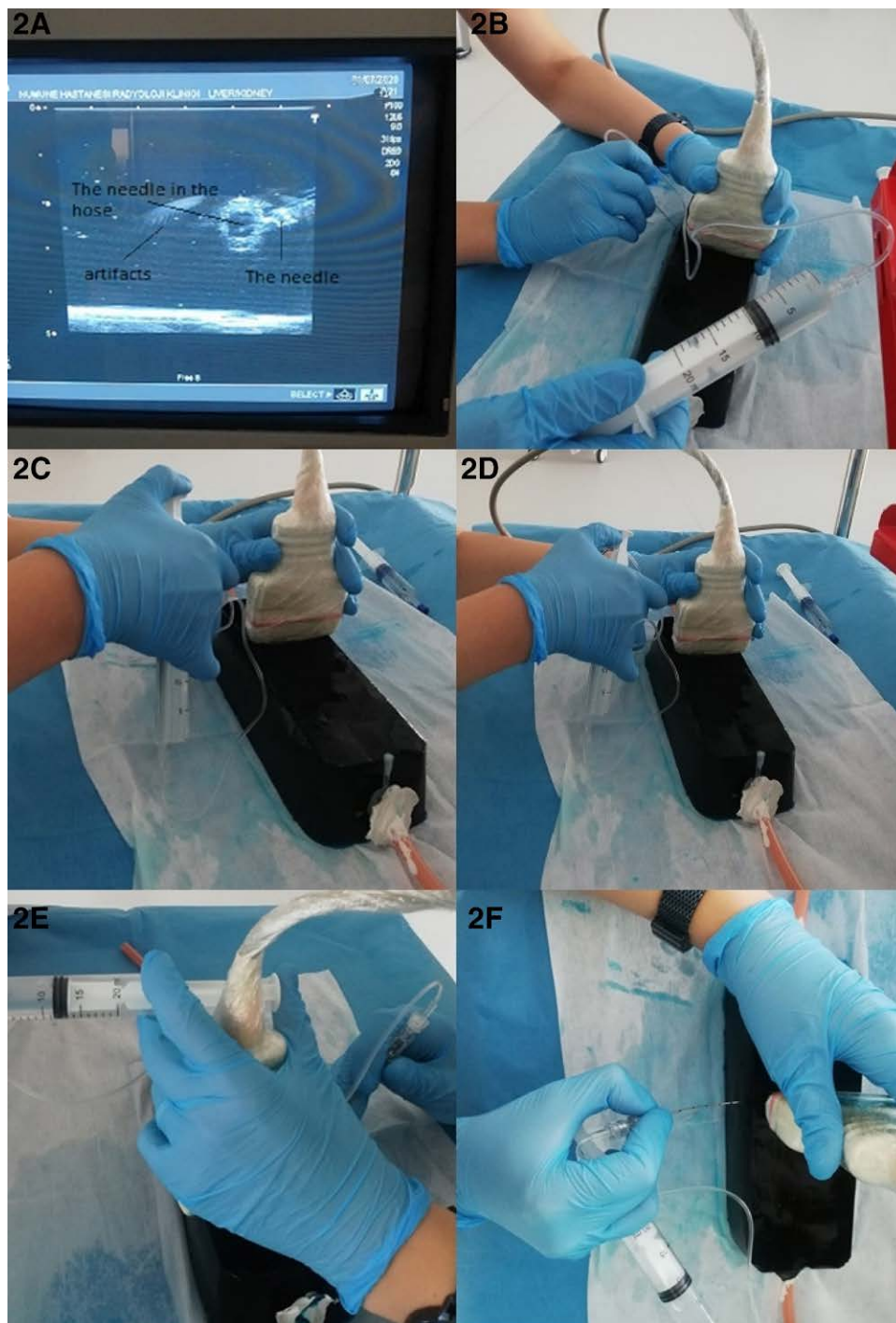

Figure 2. (A) The image of the hose in short axis view (hyperechoic area), the needle tip in the hose and peripheral artifacts in the phantom model. (B) Double operator technique. (C) In Jedi grip technique resident injects in the syringe with the thumb. (D) In Jedi grip technique resident aspirates in the syringe with the thumb. (E) On-lock grip technique. (F) Bedforth technique.

2.2. Participants

Eligible participants were volunteer anesthesia residents under 2.5 years duration of anesthesiology training in the national residency program consisting of a 5-year educational continuum. After providing written informed consent, 47 participants were included in this study (Fig. 1). The residents were asked not to share their training characteristics with each other. Demographics were collected, including age, sex, duration of anesthesiology training, and documentation of previous USG experience.

2.3. Training session

Residents engaged in two 30 minutes long training sessions. The first was a one-to-one tutorial that consisted of basic USG physics, settings, images, transducer movements, visualization of the hose in the short-axis view, in-plane needle insertion, single [Jedi,[1] On-lock,[2] Bedforth[3] grips], and double-operator USG guided regional anesthesia techniques on a homemade gelatine-based phantom. In this session, the training was theoretical and visual in nature. For the second training session, another 30 minutes residents were allowed to practice the needling techniques with single-operator grips and the double-operator technique. In this session, the trainer supervised what the participant had learned and completed the deficiencies.

2.4. Interventional tasks sessions

Residents were first asked to visualize the hose in the short-axis view. Second, an in-plane approach was used to position the needle tip in the targeted area in the phantom, as shown in Figure 2A. Each resident was included in all 4 groups in each session. The orders of application of 4 techniques (groups) were randomly determined by the closed envelope method by each resident. The instructor demonstrated the technique prior to each task. This protocol was followed in each of the 3 sessions, applied at 1-week intervals. The same USG machine probe (8 MHz linear probe, Toshiba Nemio 10 USG machine; Toshiba Medical Systems Corporation, Otawara-shi, Japan) and the same brand block needle (21G, 100 mm, Vygon Eocoplex, France) were used for all sessions. A 20 ml syringe was used for all sessions. The USG settings were predetermined and did not change between the sessions.

In the double-operator technique, residents controlled the USG probe with 1 hand and the needle, while the same instructor assisted the resident for aspirating and injecting the solution using a syringe (Fig. 2B).

In the jedi grip technique,[1] while the dominant hand was pronated, the resident held the hub of the needle between the middle phalanx of the index finger and the middle finger, the syringe with fingers 4 and 5, and the plunger part to the thumb in the palm. The resident aspirated (in only the Jedi grip) or injected into the syringe with their thumb (Fig. 2C, D).

In the on-lock grip technique,[2] the residents held the block needle in 1 hand and the USG probe between the ring and little fingers and the syringe in the index and middle fingers. The injection was performed using the thumb (Fig. 2E).

In the Bedforth technique,[3] the residents held the needle between the index finger and thumb and depressed the syringe plunger using the middle and ring fingers and palm of the hand (Fig. 2F).

2.5. Recorded data

The time taken to perform the correct grip of the needle, syringe, and probe after the start command was recorded. Retraction of the needle from the model was defined as a failed attempt, and the number of attempts required to position the needle tip inside the hose after the start command was recorded. The time taken to position the needle tip inside the hose and successful injection (needling time) were recorded. Aspiration success was also recorded only for the Jedi grip.

USG image quality was assessed for each technique by the same instructor according to the maintaining visualization success of the needle throughout the course using a 4-point Likert scale (1 = unacceptable, 2 = fair, 3 = moderate, 4 = good).

Residents were asked to evaluate the training sessions using 2 measures on a 5-point Likert scale. Satisfaction was expressed as follows: (1) Training with the phantom was beneficial for me; (2) in terms of the use of USG and grip technique, the training was sufficient to safely perform peripheral block to patients. The answer options were as follows: 1. Absolutely I agree, 2. I agree, 3. I am indecisive, 4. I do not approve, 5. Absolutely disagree.

The workload of the techniques was evaluated by residents using the NASA-TLX, comprising 6 domains: mental demand, physical demand, temporal demand, performance, effort, and frustration levels during block performance.[9]

3. Statistical analysis

The data were statistically analyzed using IBM SPSS Statistics 20, and the accepted statistical level of significance was $P < .05$. If significance was found at the level of $P < .001$ as a result of the evaluations, the actual significance level is presented in the tables.

Descriptive statistics are summarized in terms of mean, standard deviation (SD), median, and minimum (min.) Maximum (Max) for continuous data. Values and percentiles were used for categorical data.

Shapiro–Wilk test was used for analyzing the conformance of data to normal distribution.

The differences between sessions for each method and the differences between the methods in each session were compared using the Friedman test. Friedman multiple comparison tests were used to evaluate the adjusted significance to determine the differences between sessions and methods.

Table 1

Demographic, period of training, and block experience of residents.

	n	%
Age (mean ± SD)	27.4 ± 2.20	
Median (min-max)	27 (25–35)	
Gender		
Female	24	51.1
Male	23	48.9
Period of training		
0–6 months	23	49
6–12 months	5	10.6
12–18 months	4	8.5
18–24 months	6	12.8
24–30 months	9	19.1
Block experience		
No block	28	59.6
Applied 1–10 blocks	12	25.6
Applied 10–20 blocks	5	10.6
Applied 20–30 blocks	1	2.1
Applied ≥30 blocks	1	2.1

Min-Max = minimum-maximum, SD = standard deviation.

Mann–Whitney U test was used to compare the female and male measurements.

Spearman Correlation Coefficient was used for analyzing the relationship between continuous data.

4. Results

According to the assignment determined by the closed envelope method for the first order, 18 of the residents were assigned to the double-operator group, 10 to the Jedi group, 11 to the On-lock group, and 8 to the Bedforth group. For the second order, 13 were assigned to the double-operator group, 12 to the Jedi group, 9 to the On-lock group, and 13 to the Bedforth group. For the third order, 11 were assigned to the double-operator group, 11 to the Jedi group, 12 to the On-lock group, and 13 to the Bedforth group. For the fourth order, 5 were assigned to the double-operator group, 14 to the Jedi group, 15 to the On-lock group, and 13 to the Bedforth group.

The demographics and block experience of the residents are summarized in Table 1. There were no gender differences in the task performance.

In Table 2, the main outcomes of the study reflecting the impact of education on performance, time to perform the correct grip, number of attempts, and needling time are given. The time to perform the correct grip and needling decreased significantly as the sessions progressed in the double operator tasks ($P < .001$). These parameters also gradually decreased in the single-operator techniques as the sessions progressed ($P < .001$). Single-operator tasks required a longer time to correct the grip compared to double-operator tasks ($P < .001$). Needling time was significantly shorter in the double operator task than in the single-operator task in only 2nd session ($P = .02$). When single-operator techniques were compared in terms of time to correct grip and needling time parameters, no difference was found in the 1st, 2nd and 3rd sessions. There was no difference between single and double-operator techniques and sessions in terms of the number of needling attempts.

Table 2

Main outcomes of the study; time to correct grip (s), number of attempts and needling time (s) to position the needle tip to the target area and successful injection for techniques and Ultrasound image quality score (1 = unacceptable 2 = fair, 3 = moderate 4 = good) assessed by instructor for techniques in sessions.

		1st Session Mean ± SD Median (min-max)	2nd Session Mean ± SD Median (min-max)	3rd Session Mean ± SD Median (min-max)	P*
Time to correct grip (s)	Double Operator	6.9 ± 4.9 6 (2–25)	5.3 ± 3.2 5 (2–17)	4.1 ± 2.4 4 (1–13)	**<.001**
	Jedi	22.2 ± 12.3 19 (7–60)	13.7 ± 7.5 13 (4–35)	10.6 ± 5.3 10 (3–24)	**<.001**
	On-lock	19.9 ± 11.7 17 (5–50)	14.4 ± 7.7 13 (4–38)	11.5 ± 8.3 9 (2–40)	**<.001**
	Bedforth	23.3 ± 13.5 18 (7–64)	17.6 ± 9.9 15 (4–52)	13.1 ± 7.6 12 (2–43)	**<.001**
P*		**<.001**	**<.001**	**<.001**	
Number of attempts	Double Operator	1.5 ± 0.8 1 (1–3)	1.2 ± 0.5 1 (1–3)	1.1 ± 0.3 1 (1–2)	**.002**
	Jedi	1.6 ± 0.7 2 (1–4)	1.4 ± 0.6 1 (1–3)	1.5 ± 1.6 1 (1–12)	.054
	On-lock	1.6 ± 0.8 1 (1–4)	1.4 ± 0.6 1 (1–3)	1.4 ± 0.6 1 (1–3)	.284
	Bedforth	1.6 ± 0.7 1 (1–3)	1.3 ± 0.5 1 (1–3)	1.3 ± 0.5 1 (1–3)	.175
P*		.786	.252	**.022**	
Needling time to position the needle tip to the target area(s)	Double Operator	18.3 ± 12.7 14 (3–62)	12.4 ± 7.1 12 (3–34)	9.7 ± 5.9 8 (2–28)	**<.001**
	Jedi	25 ± 20.5 20 (6–120)	17.9 ± 10.2 16 (5–55)	13.5 ± 13.2 11 (3–73)	**<.001**
	On-lock	27.6 ± 20.6 21 (5–87)	17.7 ± 12.7 13 (5–46)	12.3 ± 7.8 11 (2–35)	**<.001**
	Bedforth	21.2 ± 13.7 19 (2–68)	15.2 ± 9.7 12 (3–43)	10.6 ± 6.3 9 (3–32)	**<.001**
P*		.445	**.020**	.214	
		Median (min-max)	Median (min-max)	Median (min-max)	p*
USG image quality	Double operator	3 (1–4)	3 (2–4)	4 (2–4)	.094
	Jedi	3 (2–4)	3 (2–4)	4 (2–4)	**.012**
	On-lock	3 (1–4)	4 (1–4)	3 (2–4)	**.001**
	Bedforth	3 (2–4)	4 (2–4)	4 (2–4)	.432
P*		**.015**	.541	.602	

Bold font indicates statistical significance.
* Friedman multiple comparison test. $P < .05$ significant.
Min-Max = minimum-maximum, SD = standard deviation, USG = Ultrasound.

All residents were able to position the needle tip inside the hose and administer 20 ml water through it for all techniques in all sessions. Using the Jedi technique, 41 (87.2%) residents were able to aspirate the syringe inside the hose during all sessions.

USG image quality was not statistically different between the techniques in the second and third sessions. The difference in image quality of the techniques in the first session was not statistically different according to the adjusted p (Adj. Sig.) values by examining the techniques that caused the difference. Similarly, the difference in image quality of Jedi between sessions was not statistically different according to the Adj. Sig values. The USG image quality of the on-lock grip in the second session was superior to that in the first (P = .001). Table 2 presents the results.

The workloads of the techniques listed in Table 3 were measured using the NASA-TLX, comprising 6 domains: mental demand, physical demand, temporal demand, performance, effort, and frustration levels during block performance. Single-operator grips had a higher workload in all domains for executing the tasks compared to the double-operator techniques (P < .001). The Jedi technique was rated lower than the Bedford technique in performance (P = .035) and both other techniques in frustration (Jedi vs On-lock, P = .006; Jedi vs Bedforth, P = .013).

Data related to the training questionnaire are showed that 46 (97.9%) residents reported training was beneficial and 39 (82.9%) residents were confident enough to perform the single-operator techniques after training as shown in Table 4.

5. Discussion

There is a lack of studies in the literature regarding single-operator USG guided regional anesthesia since their definition.[1–3] Although these techniques have some advantages such as continuous tactile feedback of injection pressure, providing the optimal amount of local anesthetic to the targeted area, and reduction in the number of employees, they are more complex and difficult than double operator techniques. We believe that the reason why it is not preferred by anesthetists in clinical practice may be the lack of training in the curriculum of residency programs.

To our knowledge, this is the first study comparing single-and double-operator USG guided regional anesthesia techniques in terms of progress in needling success in a phantom model after a structured training. In the literature, Keklik et al showed that the single-operator jedi technique and double-operator technique were similar in terms of block success and complications in axillary block, and they showed that the single-operator technique can be successfully used in USG guided peripheral nerve blocks.[11]

This study shows that inexperienced anesthesia residents could increase efficiency when performing both the single-and double-operator needling techniques by training with a simple and inexpensive hand-made phantom. The time to perform the correct grip of needle, syringe and USG probe decreased significantly in all techniques as the sessions progressed. Needling time to position the needle tip to the target area in the phantom also decreased significantly in all techniques as the sessions progressed. There was no gender difference in the performance of the interventional tasks of the single operator grips compared to the double operator techniques.

Single-operator grips have a higher workload in all domains of the NASA-TLX for executing the tasks compared to the double-operator techniques as expected. The Jedi technique was rated lower than the Bedford technique in performance domain and other techniques in frustration domain. However, the clinical significance of these are unclear considering that 39 (82.9%) assistants were confident enough to apply single-operator techniques after training despite attending only 3 interventional task sessions,

Table 4

Distribution of residents' opinions related with the training.

	n	%
Training with Phantom was beneficial for me		
Strongly agree	42	89.4
Agree	4	8.5
Neutral	1	2.1
Disagree	–	–
Strongly disagree	–	–
The training was good enough in terms of single operator gripping techniques to confidently perform peripheral block to patients		
Strongly agree	11	23.4
Agree	28	59.6
Neutral	5	10.6
Disagree	3	6.4
Strongly disagree	–	–

Table 3

The workload measurements of techniques using NASA-TLX.

	Double Operator	Jedi	On-lock	Bedforth	P*
	Mean.±SD Median (Min-Max)	Mean.±SD Median (Min-Max)	Mean.±SD Median (Min-Max)	Mean.±SD Median (Min-Max)	
Mental demand	1.32 ± 0.66 1 (1–4)	4.26 ± 1.94 4 (1–10)	5.36 ± 2.42 5 (1–10)	5.60 ± 2.13 6 (1–9)	**<.001**
Physical demand	1.26 ± 0.61 1 (1–4)	4.06 ± 2.34 3 (1–10)	5.60 ± 2.40 6 (1–10)	5.45 ± 1.94 6 (1–9)	**<.001**
Temporal demand	1.51 ± 0.69 1 (1–4)	4.28 ± 1.74 4 (1–8)	5.89 ± 2.36 6 (1–10)	5.36 ± 2.07 5 (1–10)	**<.001**
Effort	1.40 ± 0.71 1 (1–4)	4.36 ± 2.12 4 (1–10)	5.83 ± 2.40 6 (1–10)	5.47 ± 1.98 5 (2–9)	**<.001**
Performance	1.94 ± 1.47 2 (1–8)	3.55 ± 1.92 3 (1–8)	4.83 ± 2.34 5 (1–9)	4.98 ± 2.02 5 (1–9)	**<.001**
Frustration	1.68 ± 0.93 1 (1–4)	4.17 ± 2.16 4 (1–10)	6.23 ± 4.42 6 (1–10)	5.68 ± 2.14 6 (2–10)	**<.001**

Bold font indicates statistical significance.

Min-Max: minimum-maximum, NASA-TLX: National Aeronautics and Space Administration Task Load Index, SD: standard deviation.

*Friedman multiple comparison test. P < .05 significant.

Image acquisition, anatomical interpretation, and hand-eye coordination are essential skills for a successful USG guided block, and a majority of residents face an extensive learning curve.[7] The American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anesthesia and Pain Therapy (ASRA-ESRA) proposed implementing simulation training in the curriculum of residency programs.[8] In single-operator techniques, the procedure becomes more difficult, and residents require more practice, as the operator focuses on holding the needle and syringe. Hands-on training of regional anesthesia in phantoms may provide a suitable environment to acquire single-operator regional anesthesia skills without risking the health and safety of patients.

Our study has some limitations. One of these limitations is that approximately 40% of the residents have different levels of block experience. The eligibility criteria were determined according to the curriculum applied in our country, considering that residents under 2.5 years duration of anesthesiology training will not apply blocks and will not have sufficient experience. Nevertheless, only 15% of the participants declared that they had applied more than ten blocks. In addition, none of the participants had attended systematic simulation training.

Although gelatine-based models are acceptable for training,[12,13] the low fidelity of our handmade gelatin-based phantom may be another limitation of our study. First, the low background echogenicity of the phantom enhanced the visibility of the block needle, and the flat surface of the phantom facilitated the probe movements. In addition, the fact that it does not reflect anatomical features causes the phantom to be unrealistic. All of these reasons make it uncertain whether the attained skills will achieve success in real patients. Further studies are required to determine the success of single-operator grip techniques and whether the techniques are superior to each other in patients.

In conclusion, our results suggest that single-operator USG guided regional anesthesia skills can be learned by simulations using cheap, hand-made gelatine-based phantoms.

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Author contributions

All authors in this paper read and approved the final manuscript
Conceptualization: BGA, İA
Data curation: BGA, ŞÜ, İA.
Formal analysis: BGA, İA.
Investigation: BGA, ŞÜ, İA.
Methodology: BGA, ŞÜ, İA.
Project administration: BGA, İA.
Resources: BGA, ŞÜ, İA.
Supervision: BGA.
Visualization: ŞÜ, İA.
Writing—original draft: BGA, İA.
Writing—review & editing: BGA, ŞÜ.

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