Comparison of human cadaver and blue phantom for teaching ultrasound-guided regional anesthesia to novice postgraduate students of anesthesiology: A randomized controlled trial

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Abstract

Background and Aims: Simulation is increasingly used in medical teaching. Various studies have evaluated different simulation models for training of regional anesthesia (RA). We compared the use of human cadaver and blue phantom models for training of regional anesthesia to novice postgraduate students of anesthesiology.
Material and Methods: Fifty students were taught knobology of the ultrasonography (USG) machine. They were divided into two equal groups by computer-generated random number table, and the groups assigned were kept in sealed envelopes. In group BP, students were trained on a blue phantom model, and in group HC, students were trained on human cadaver. After training, a didactic video of sonoanatomy of the supraclavicular block was shown to all participants. The block performance was then judged on patients requiring supraclavicular block. The primary objective of the study was to compare the block performance time, and secondary objectives were the quality of image acquired, orientation of transducer to the target, identification of ultrasound artifacts, errors committed, complications, and success rate.
Results: The mean block performance time was shorter in group HC compared to group BP (451.96 ± 50.25 and 526.48 ± 43.486 s, respectively; $P < 0.001$). The image quality score, transducer orientation to the target, and identification of USG artifacts were better in group HC compared to group BP, with lesser number of needle passes.
Conclusion: Cadaver-based training produced better results compared to blue phantom simulator model for teaching of ultrasound-guided RA to novice postgraduate trainees of anesthesiology.

Keywords: Cadaver, resident training, simulation, ultrasound-guided regional anesthesia

Introduction

With the advent of ultrasonography (USG) in the armamentarium of anesthesiologists, regional blocks are performed more precisely. USG helps in visualization of neurovascular bundle and drug spread around the nerve, thus improving the nerve block success rate while reducing procedure-related complications. Ultrasound-guided regional anesthesia (UGRA) requires less volume of local anesthetic (LA) compared to landmark technique, hence there is decreased incidence of local anesthetic systemic toxicity (LAST).[1,2] Despite the increasing use of USG,

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Access this article online	
Quick Response Code:	Website: https://journals.lww.com/joacp
	DOI: 10.4103/joacp.joacp_234_22

How to cite this article: Dang D, Kamal M, Kumar M, Paliwal B, Nayyar A, Bhatia P, *et al*. Comparison of human cadaver and blue phantom for teaching ultrasound-guided regional anesthesia to novice postgraduate students of anesthesiology: A randomized controlled trial. J Anaesthesiol Clin Pharmacol 2024;40:276-82.

Submitted: 28-Jun-2022 **Revised:** 18-Sep-2022
Accepted: 19-Oct-2022 **Published:** 16-May-2024

the curriculum of anesthesiology training does not have a standardized training module for UGRA.[3] A successful UGRA involves knowledge of anatomy, image acquisition, interpretation of sonoanatomy, hand–eye coordination, and visualization of needle tip and drug around the target nerves. A learning curve has been described for the acquisition of simulation-based UGRA skills by residents.[4] It helps a novice to correct errors, gain motor skills, and allow time to develop expertise before performing regional nerve block procedures on the patients.

Various types of phantom models like water, tofu, gelatin, elastomeric rubber, blue phantom, and human cadavers are available. Each model has its advantages and disadvantages in terms of fidelity, cost, and availability.[5,6] The basic skills of UGRA can be taught on blue phantom model and human cadavers. However, it is not known which model among them is better to teach UGRA to novice trainees of anesthesiology.

Blue phantom of CAE Healthcare USA (www.caebluephantom.com), made of patented ultra-durable tissue (elastomeric rubber), which has similar acoustic properties to human tissue, can be used for teaching UGRA, but is costly. Gelatin phantoms and blue phantoms provide tactile feedback, but have very low background echogenicity, which greatly exaggerates needle visibility. This makes skill acquisition easier, but can lead to false confidence with regard to clinical ability. Fresh-frozen cadavers retain much of the textural feel of live human tissue and are nearly as echogenic. Fresh-frozen cadavers were used in our study to practice UGRA, and median nerve of the forearm was used as the target at a depth below the skin surface.

Purpose of this study was to compare two training models in terms of their efficacy and safety to teach UGRA to novice trainees of anesthesiology.

Chuan *et al.*[7] compared two organic phantom models such as meat model and cadaver. To the best of our knowledge, no study is available which compared the blue phantom model and human cadaver for teaching UGRA to novice trainees of anesthesiology. Hence, with this study, we planned to compare an organic model like cadaver with inorganic blue phantom model.

The hypothesis of this study was that human cadaver and blue phantom model are equally efficacious in training of UGRA. Our aim was to compare the efficacy of human cadaver with blue phantom model for teaching UGRA to novice trainees, and outcome assessment was done on patients requiring supraclavicular brachial plexus block for surgical procedure on the upper limb. The efficacy of the training method was judged during supraclavicular brachial plexus block on patients. The primary objective was comparison of block performance time, and secondary objectives were image acquisition quality, transducer orientation to the target, identification of ultrasound artifacts, errors related to the procedure, complications, and success rate of ultrasound-guided supraclavicular brachial plexus block.

Material and Methods

The study was conducted after obtaining approval from the institutional ethics committee and was registered at the Clinical Trial Registry-India (CTRI/2019/07/020069, dated 08/07/2019). This single-center, prospective, randomized controlled study was conducted in a tertiary care hospital from August 2019 to March 2021. Fifty novice trainees of anesthesiology who did not have prior regional anesthesia experience were enrolled in this study. Exclusion criteria were students who had already been trained or had performed UGRA and those who did not give consent for participation. All participants were shown a 20-min video demonstrating ultrasound knobology, physics, and transducer movements related to UGRA. Participants were then randomly divided into two groups of 25 each using computer-generated random number table [Figure 1]. Allocation concealment was done using the sequentially numbered, opaque, sealed envelope (SNOSE) method.

In group BP, the participants were trained on nerve-based blue phantom model, a regional anesthesia ultrasound training block model. This model delivers a realistic, quality ultrasound image [Figure 2a and b]. In group HC, the participants were trained to hit the median nerve at wrist on fresh human cadavers which are frozen to −17°C and then defrosted at a temperature between +3°C and +5°C before use [Figure 3].

The training sessions were conducted by using USG machine (LOGIQ E NextGen ultrasound, GE Healthcare) and high-frequency linear array ultrasound probe (5–13 MHz, 38-mm footprint), and the same machine was used for assessment. The blunt tip ultrasound block needles (20 G, 50 mm; Stimuplex A; B. Braun, Melsungen AG, Germany) were used for training as well as for block performance. The block was performed in a short-axis in-plane approach. Expert feedback and guidance were given after each attempt by consultant anesthesiologist during training. All participants were given a maximum of 30 attempts to practice on their allocated training model.

After training, all participants were shown a video demonstrating sonoanatomy of the supraclavicular area and inline short-axis

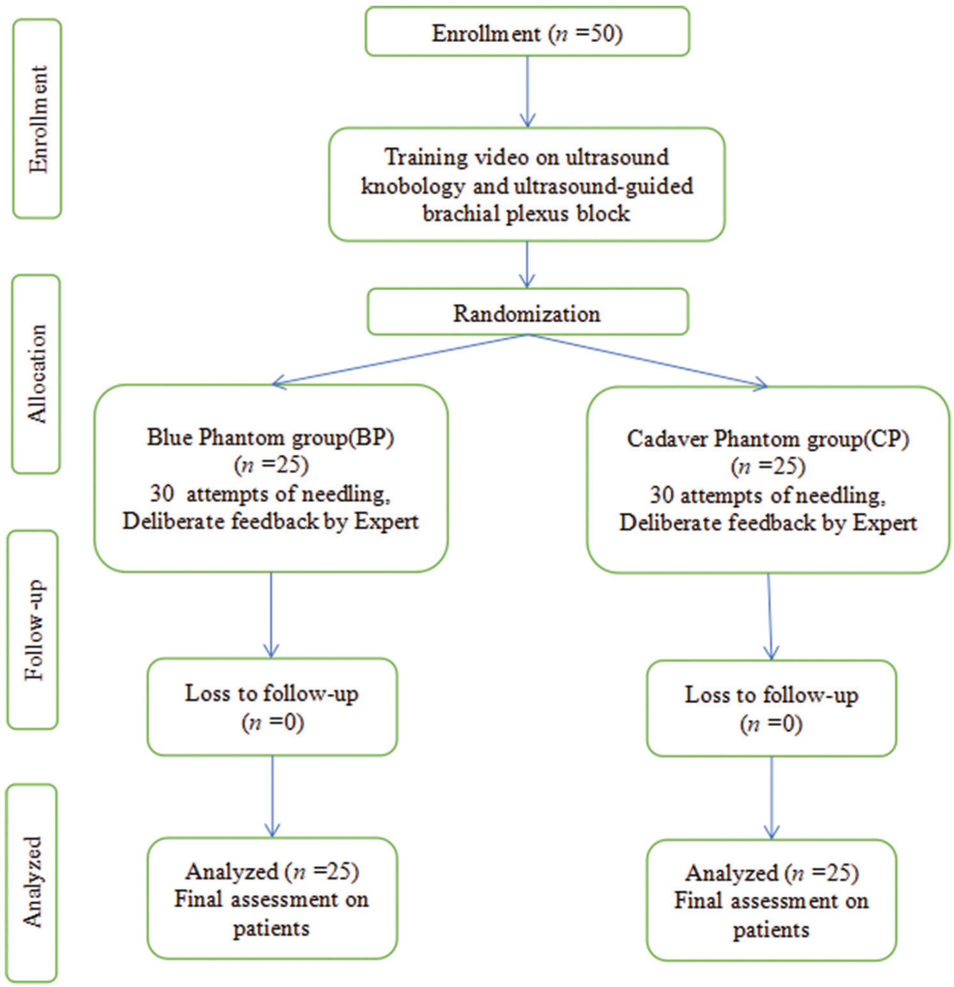

Figure 1: Consort flow chart

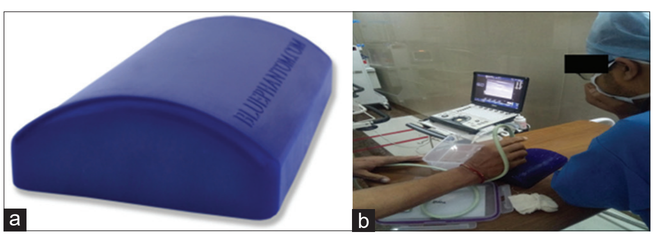

Figure 2: (a) CAE blue phantom model. (b) Training on blue phantom model

technique of supraclavicular brachial plexus block. No interaction was allowed between participants throughout the study. The participants were assessed on patients requiring supraclavicular brachial plexus block for upper limb surgery, after taking informed consent from the patients.

The block was performed with the same USG machine, probe, and needle, which were used during training. All blocks were performed under the supervision of a consultant anesthesiologist, and outcome assessment was done by another consultant anesthesiologist who was not aware of the group allocation. The block performance time was defined as the time from picking up the transducer to successful deposition of injectate above and below the brachial plexus.

The quality of image was scored on four-point parameters; 4: outstanding = unequivocal with the complete neural structure visualized; 3: satisfactory = unequivocal with an incomplete definition of the neural structure; 2: poor = equivocal image; and 1: inadequate image. Transducer orientation to the target was scored as 0: transducer steady and nerve imaged adequately in the field of view and 1: transducer unsteady or nerve not adequately centered in the field of view. Identification of ultrasound artifacts such as acoustic shadowing, acoustic enhancement, reverberation artifact, bayonet artifact, and resolution artifacts was noted as per their definitions.

Errors noted included (a) unstable hand grip once needling starts (means 75% of the procedure time, the hand is not anchoring to hand/fingers on the model), (b) hand fatigue (defined as change of hands-on transducer during the procedure, or lifting transducer off the skin surface), (c) advancing needle without visualizing the tip, (d) unstable transducer movements resulting in loss of image, (e) unstable needle movements causing loss of needle image, and (f) intraneural needle passes or injections.

Success of block (defined as patients not requiring general anesthesia for completion of surgical procedure) and procedural complications (artery puncture, hematoma, pleural puncture, LAST, and any nerve injury) were noted. All patients were followed for 24 h and at 1-week postoperative visit to detect any issues that were not identified during the surgery (i.e. infection, pneumothorax, persisting sensory, or motor dysfunction).

Sample size calculation was based on the previous study by Chuan *et al.*[7] using estimated mean block performance time of 294 and 237 s in the two groups, power of the study 90%, pooled standard deviation (SD) 58.84, and two-tailed significance level of 0.05 or 5% We obtained a sample size of 23 in each group and included 25 participants in each group to cover any contingency.

Statistical analysis

The data were entered in Microsoft Excel spreadsheet and analyzed using Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA) version 20. The normality distribution of data was checked by the Kolmogorov–Smirnov test, and data were found to be normally distributed. Quantitative data between the two groups were compared by independent *t*-test (Student's *t*-test), and ordinal data were compared using Mann–Whitney U test, Fisher's exact test, and Chi-square test, wherever applicable. P value <0.05 was considered significant.

Results

Totally 50 participants were recruited and analyzed [Figure 1]. The gender distribution and body mass index (BMI) of patients were comparable between the groups. The mean (SD) block performance time was 451.96 (50.25) s in group HC and 526.48 (43.486) s in group BP ($P < 0.001$) [Table 1 and Figure 4]. Image quality score, transducer orientation to the target (transducer steady and nerve imaged adequately in the field of view), and identification of USG artifacts (acoustic shadowing and reverberation) showed a statistically significant difference between the groups ($P = 0.003$, 0.009, 0.037, and 0.012, respectively) [Table 2]. Among the errors committed, advancing the needle without visualizing the tip was statistically significant ($P = 0.01$) [Table 3]. Success rate and complications between the groups were comparable.

Figure 3: Training on cadaveric model

Discussion

Our study showed that novices trained on human cadaver require less time to perform ultrasound-guided supraclavicular brachial plexus block and obtain better image quality score and transducer orientation to the target compared to those trained on blue phantom.

During anesthesiology training, regional anesthesia was conventionally taught using diagrams, models, and anatomic

Table 1: Patient's demographic data, block performance time

	Group BP (n=25)	Group HC (n=25)	P*
Sex (M/F)[a]	20/5	21/4	0.715
BMI[b]	24.16±2.72	23.66±3.21	0.555
Block performance time[b]	526.48±43.48	451.96±50.25	<0.001

*BMI=body mass index, SD=standard deviation. [a]Number for gender distribution between groups; Chi-square test used for analysis. [b]Mean±SD for BMI and block performance time; Student's t-test used for analysis. *P<0.05 was considered significant*

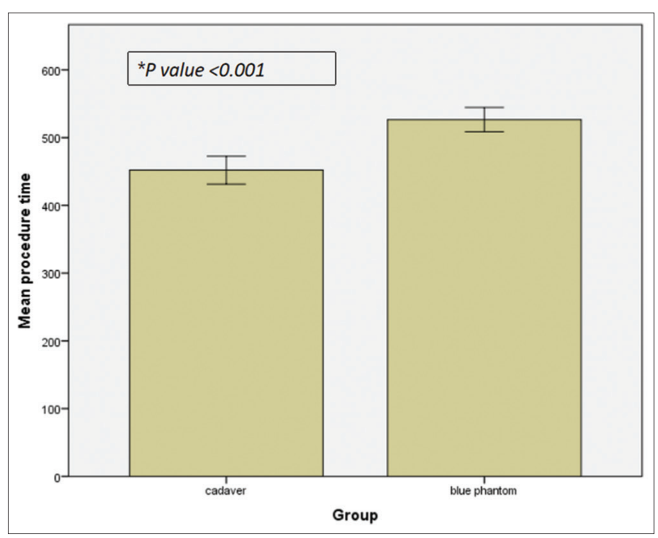

Figure 4: Mean block performance time in groups

Table 2: Image quality score, number of needle passes, transducer orientation to the target, and identification of USG artifacts

	Group BP (*n*=25)	Group HC (*n*=25)	*P**
Image quality score[a]	3.0 (2-3)	3.0 (3-4)	0.003
Number of needle passes[a]	2.0 (2-2.5)	2.0 (1-2)	0.005
Transducer orientation to the target (transducer steady and nerve imaged adequately in the field of view)[b]	18 (72)	25 (100)	0.009
Identification of USG artifacts[b]	10 (40)	23 (92)	<0.001
Acoustic shadowing[b]	5 (20)	13 (52)	0.037
Acoustic enhancement[b]	3 (12)	3 (12)	1.0
Reverberation artifact[b]	3 (12)	12 (48)	0.012
Bayonet artifact[b]	0	0	-
Resolution artifact[b]	1 (4)	1 (4)	1.0

*USG=ultrasonography. [a]The image quality score and number of needle passes are presented as median (IQR); Mann-Whitney U test used for analysis. [b]Values are presented as number and percentage; Fisher's exact test used for analysis. *P value <0.05 was considered significant*

Table 3: Errors committed

	Group BP (*n*=25)	Group HC (*n*=25)	*P**
Unstable hand grip once needling starts[a]	11 (44)	11 (44)	1.0
Hand fatigue[a]	17 (68)	11 (44)	0.094
Advancing needle without visualizing the tip[a]	19 (76)	10 (40)	0.012
Unstable transducer movements causing loss of needle image[a]	12 (48)	10 (40)	0.564
Unstable needle movements causing loss of needle image[a]	12 (48)	11 (44)	0.771
Total errors[b]	14.2±3.56	10.6±0.54	0.562

*SD=standard deviation. [a]Individual error values are presented as number and percentage; Chi-square test used for analysis. [b]Total errors are presented as mean±SD; independent t-test used for analysis. *P<0.05 was considered significant*

guidance.[3] USG helps in visualizing the target in real time and also helps in guiding the needle. Various types of models have been used for requisite training of UGRA.[8,9] Simulation-based training has been shown to increase the success rate of regional nerve blocks.[10] Simulated practice increases the proficiency of novices in using UGRA in terms of knowledge and skills.[11,12]

The training in technical procedures in anesthesiology is unsystematic and unstructured, as few opportunities are given to novices because of decreased tolerance of medical errors. Moreover, it is unethical for novice trainees to practice new skills on patients even with consent from the patients. Simulation-based training is taking over the traditional methods of teaching like "apprenticeship model" or "see one, do one" methods for nearly all sorts of procedures in anesthesiology.[13,14]

Simulation-based training allows development of procedural and nontechnical skills like task management, leadership, teamwork, situation awareness, and decision-making in simulation centers, without endangering the patients. Simulation reduces the errors and is focused on requirements of the trainee.[14]

The American Society of Regional Anesthesia and Pain Medicine (ASRA) and the European Society of Regional Anesthesia and Pain Therapy (ESRA) have jointly published guidelines for simulation-based training in UGRA.[15] These guidelines encourage the use of phantom models for simulation in UGRA training. The inorganic material (blue phantom) models can be used to teach procedural techniques, dexterity, target structure identification, and needle visibility, but they often lack true tactile feeling and haptic feedback; also, liquid solutions cannot be injected in them.[5] In contrast, organic models like cadaver arguably produce a more realistic sonoanatomy and tactile sensation and allow for injection. Cadavers are most easily accessible and closely replicate the clinical experience. Cadavers allow for accurate identification of anatomy, identification of fascial layers during needle insertion, ergonomics, and are nearly as echogenic; they are also a good teaching tool. They are biodegradable, and their anatomy gets distorted with use; so, they need to be replaced for subsequent training sessions.[5,16] In previous studies, participants had expressed high satisfaction and increased confidence, and they firmly believed that cadavers offer high educational value in teaching airway, intensive care skills, and UGRA.[7,17-19]

In this study, we observed that the time taken to perform supraclavicular brachial plexus block was lesser in cadaveric group compared to blue phantom group [Table 1, Figure 4]. Chuan *et al.*[7] compared meat-based model with human cadaver for teaching UGRA and they observed that the time taken to perform sciatic nerve block was comparable in both groups. They suggested that meat model can be used to teach novices in early scanning and needle-handling skills relevant for UGRA.

Previous studies had also suggested that minimum of 28–30 attempts are required for a novice to gain competence; so, we had given 30 attempts to each novice trainee to practice UGRA.[7,20]

Image quality score was found to be better in participants trained on cadaver compared to participants trained on blue phantom [Table 2]. The quality of image depends on probe selection, technique of USG, ergonomics, and hand stability; hence, it should have been comparable in both groups. The difference in image quality score can be explained by the difference in performance of echogenic needle in blue phantom compared to that in human tissue. The visibility of the needle is better in blue phantom due to low background echogenicity, which facilitates skill learning, but may mislead novices in terms of clinical competency and give trainees a false confidence.[5] Chuan *et al*.[7] did not find any difference in image quality score because they used an organic phantom in both groups.

The transducer orientation to the target was found to be better (transducer steady and nerve imaged adequately in the field of view) in the cadaveric group in our study [Table 2]. The probable reason for this is the participants who were trained on cadaver kept the transducer steady since they had an awareness of performing the procedure on human body/tissue, while those who practiced on blue phantom were subconsciously aware of its artificial nature and had a lenient way of handling the transducer.

In our study, the most common USG artifacts identified by participants were acoustic shadowing and reverberation artifact [Table 2]. Advancing the needle without visualizing the tip was noticed more in participants trained on blue phantom because of poor image acquisition in this group. Similar findings were obtained in previous studies.[7,21] Total number of errors was found to be comparable with no significant difference between both groups [Table 3]. The success rate of supraclavicular brachial plexus block was similar in both groups. This could be because of the adequate number of needling attempts given during the training and directed feedback given by the consultants irrespective of the model used for training. No patient in either group required conversion to general anesthesia during the surgery, which indicates that nerve block was successful in all patients of both groups [Table 4]. Arterial puncture during performance of block was seen in only one patient in group BP. At 1-week postoperative period, no patient in either group identified any delayed procedural complications like infection at the site and persistent sensory or motor deficits.

Limitations of this study are as follows: (a) lack of a validated assessment tool for USG image interpretation; (b) "nontechnical skills" (visuospatial and psychomotor) were not assessed; (c) multiple cadavers were used for training of participants in the cadaveric group; (d) the aptitude of participants for UGRA skills was not assessed; (e) supraclavicular brachial plexus-based blue phantom model was not used for training; and (f) overall incidence of complications in our study was low, so the beneficial effect of training on reducing complications cannot be commented upon.

Table 4: Nerve block success rate and complications

	Group BP	Group HC	*P**
Nerve block success rate[a]	25 (100)	25 (100)	-
Artery puncture[a]	1 (4)	0	-
Hematoma[a]	0	0	-
Pleural puncture[a]	0	0	-
LAST[a]	0	0	-
Nerve injury[a]	0	0	-

*LAST=local anesthetic systemic toxicity. [a]Nerve block success rate and complications are presented as number and percentage. *P value <0.05 was considered significant*

Conclusion

Human cadavers offer a better training model in terms of less block performance time, number of needle passes, better quality of image, and transducer orientation to the target compared to blue phantom model. Simulation-based training is highly successful for performing supraclavicular brachial plexus block for upper limb surgeries.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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