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# Evaluating virtual reality anatomy training for novice anesthesiologists in performing ultrasound-guided brachial plexus blocks: a pilot study

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## Abstract

**Background** Developing proficiency in ultrasound-guided nerve block (UGNB) demands an intricate understanding of cross-sectional anatomy as well as spatial reasoning, which is a big challenge for beginners. The aim of this pilot study was to evaluate the feasibility of virtual reality (VR)-facilitated anatomy education in the first performance of ultrasound-guided interscalene brachial plexus blockade among novice anesthesiologists. We carried out pilot testing of this hypothesis using a prospective, single blind, randomized controlled trial.

**Methods** Twenty-one anesthesia trainees with no prior ultrasonography or nerve block training were included in this study. All participants underwent a training program encompassing theory and hands-on practice. Trainees were randomized into one of two groups: one received VR-assisted anatomy course while the other did not. Subsequently, both groups completed identical practical modules on ultrasound scanning and needle insertion. The primary end point was defined as the evaluation of trainees' performance during their initial ultrasound-guided interscalene brachial plexus block, assessed using both the Global Rating Scale (GRS) and a task-specific Checklist. The secondary end point included the improvement in scores for written multiple-choice questions (MCQs).

**Results** In evaluating practical ultrasound-guided nerve block skills, the VR group significantly outperformed the control group on the task-specific Checklist (29.23 ± 3.91 vs. 24.85 ± 5.13; $P < 0.05$), while both groups showed comparable performance on the GRS. Additionally, post-theoretical course MCQ scores increased substantially, with post-test results significantly surpassing pre-test scores in both groups ($P < 0.001$). However, intergroup analysis indicated no significant difference in score improvements between the VR and control groups (21.82 ± 12.30 vs. 18.33 ± 9.68, $P > 0.05$).

**Conclusions** Overall, the findings of this pilot study suggest that immersive virtual reality training in anatomy may contribute to improving the proficiency of ultrasound-guided brachial plexus blocks among novice anesthesiologists. Incorporating VR into future anesthesia technique training programs should be considered.

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**Keywords** Ultrasound-guided nerve block, Immersive virtual reality, Anatomical competency, Anesthesiology

## Background

Ultrasound-guided nerve block (UGNB) has emerged as a critical competency for regional anesthesiologists, coinciding with the expanded implementation of ultrasonography in clinical practice. UGNB markedly increases the success rate of nerve block and concurrently diminishes the occurrence of complications [1]. However, for novice anesthetists, the rapid acquisition of UGNB proficiency poses a considerable challenge, because it requires the mental integration of multiple bidimensional (2D) images to construct a three-dimensional (3D) perception of anatomy [2]. Trainees with poor visual-spatial abilities may find it particularly difficult in interpretating ultrasound imagery and achieving precise hand-eye coordination during needle insertion.

To attain clinical proficiency in UGNB, a basic comprehension of anatomy is essential. Traditionally, anatomy pedagogies rely on human cadaveric dissections and the use of 2D images in didactic lectures. During postgraduate education, a noticeable trend of reduced instructional hours and restricted access to cadaveric resources has emerged [3]. These limitations contribute to an increased time investment and diminished efficiency in acquiring proficiency in UGNB. Consequently, traditional approaches to training are being reevaluated considering these challenges.

Due to the rapid advance in 3D computer graphics technology, virtual reality (VR) technology has been increasingly used in the field of medical education and training. Owing to its immersive and interactive nature, VR enables trainees to visualize and interact with complex structures and systems in a way that is not possible with traditional methods [4]. By incorporating head-mounted displays (HMDs), immersive VR environments could block visual cues from the physical environment and offer a stereoscopic view of virtual content in all directions [5]. Research suggests that immersive VR has the potential to alleviate the cognitive load inherent in skills training [6]. Moreover, empirical evidence supports the effectiveness of VR in anatomy education, demonstrating improvements in both knowledge comprehension and retention, as well as the acquisition of practical competencies, such as surgical procedures [7].

Previous research suggests that virtual reality anatomy training enhances ultrasound operation skills [7]. However, its effect on the proficiency in ultrasound-guided nerve block techniques remains unclear. This pilot study aimed to evaluate the feasibility of VR-assisted anatomical instruction in UGNB training among novice anesthesiologists. We hypothesized that a VR-assisted approach to teaching anatomy would more effectively facilitate skill acquisition in ultrasound-guided interscalene brachial plexus blocks compared to conventional methods.

## Methods

### Study design

This pilot randomized controlled trial was conducted at Ningbo No.2 Hospital (Ningbo, China) from March 2023 to June 2023. The study protocol was approved by the Clinical Research Ethics Committee of the Ningbo No.2 Hospital (Approval NO.SL-NBEY-KY-2022-061-01) and the study was registered with ClinicalTrials. gov (ChiCTR2300067437). Trainees were randomized to either the intervention or control group. The randomization process was conducted by an anesthesiologist (not involved in assessing outcomes) using a random numbers table. All subjects, patients and anesthesiologists, provided written informed consent.

### Study population

This study enrolled fifth-year medical students and first-year residents both majoring in anesthesiology who were on rotation at Ningbo No.2 Hospital and had completed all human anatomy courses in undergraduate education stage. All participants had completed at least a 3-month rotation in anesthesiology and had prior experience in venous and arterial catheterization. Our exclusion criteria were previous nerve block experience or any ultrasonography/UGNB training. A total of 24 participants were recruited on a volunteer basis and allocated into two groups: a VR group (VG) ($n=12$) and a control group (CG) ($n=12$). 3 participants dropped out (1 from the intervention group and 2 from the control group) due to time conflict with the skill assessment. A total of 21 participants were analyzed in this study. (Fig. 1). All trainees in both groups took part in a workshop designed for ultrasound-guided interscalene brachial plexus block. For VG, trainees received a VR-integrated course. In contrast, trainees in CG completed the course without VR.

Concurrently, patients under 60 years of age scheduled for shoulder or upper limb surgeries without significant neck pathologies were recruited in the phase of outcome assessment.

### Research objectives

The primary objective was to evaluate the effectiveness of VR-facilitated anatomy education in the first performance of ultrasound-guided interscalene brachial plexus blockade among novice anesthesiologists. Secondary

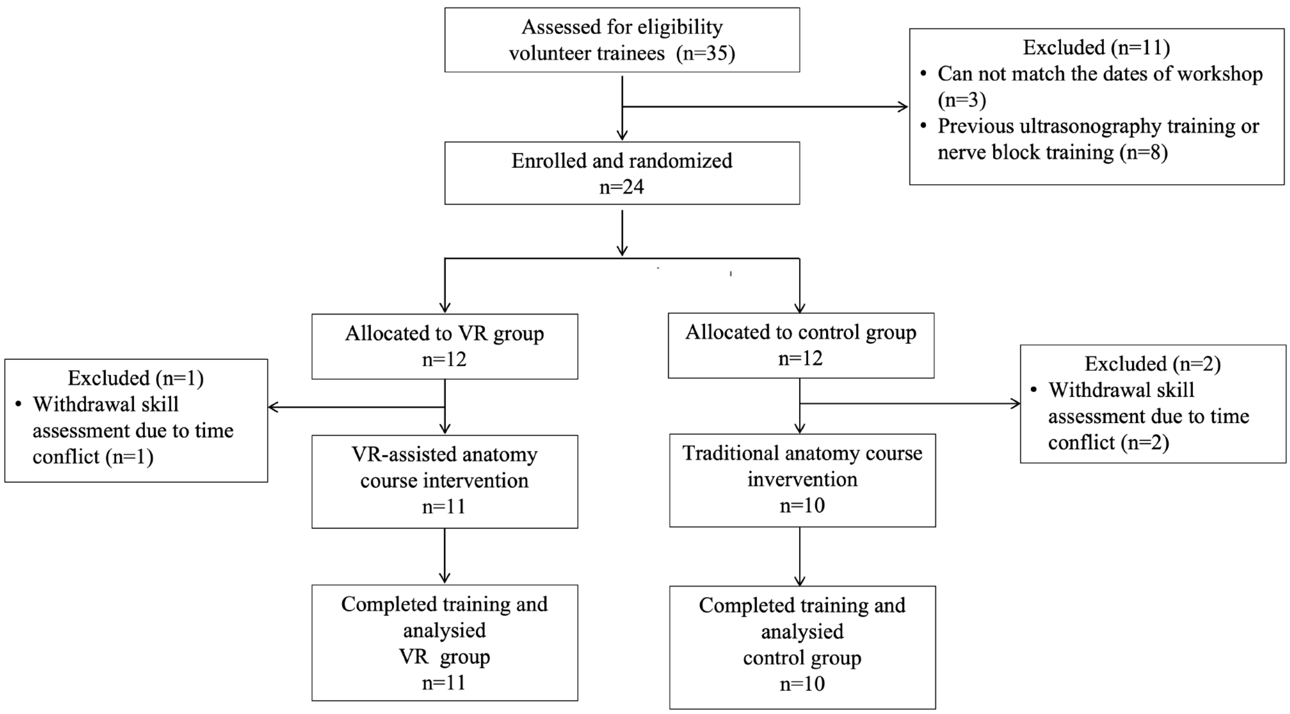


**Fig. 1** Randomization flow chart

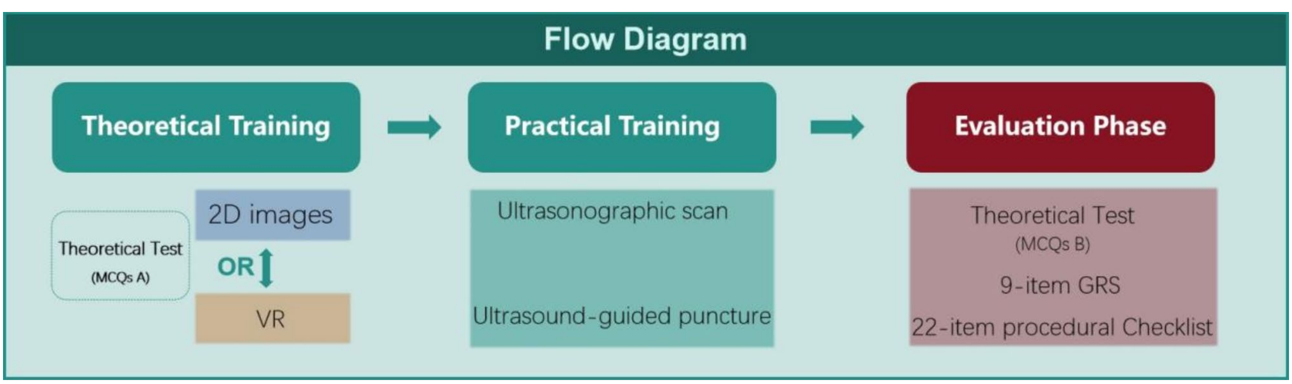


**Fig. 2** Flow diagram

objectives included assessing the improvement in theoretical knowledge using VR in educational methods.

### Curriculum design

The curriculum of UGNB training was structured around a 3-hour practical workshop, divided into two distinct stations, in combination with evaluations on theoretical knowledge and skills performance (Fig. 2). In the first station, all participants received a 90-minute theoretical course with reading material in advance. During that course, all participants were provided with a 60-minute lecture presented by one expert, imparting knowledge of ultrasound-guided interscalene brachial plexus block in a PowerPoint presentation (including anatomy, ultrasound imaging, indications, contraindications, technique, and potential complications), and a 10-minute video of an expert anesthesiologist explaining and performing nerve block was played. A pivotal distinction was introduced between the VR group and the control group: the former engaged in a 20-minute immersive VR experience using VR anatomy software, while the later was presented with 2D pictures. Participants in VR group could directly manipulate the VR model with controllers by using a head-mounted display (Fig. 3).

In the second station, a hands-on 90-minute practical session was conducted. All participants in both groups practiced ultrasonographic scan on the neck of volunteers under the instruction of an expert within 60 min, ensuring that everyone knew how to correctly identify target structures in the checklist and acquire ultrasound

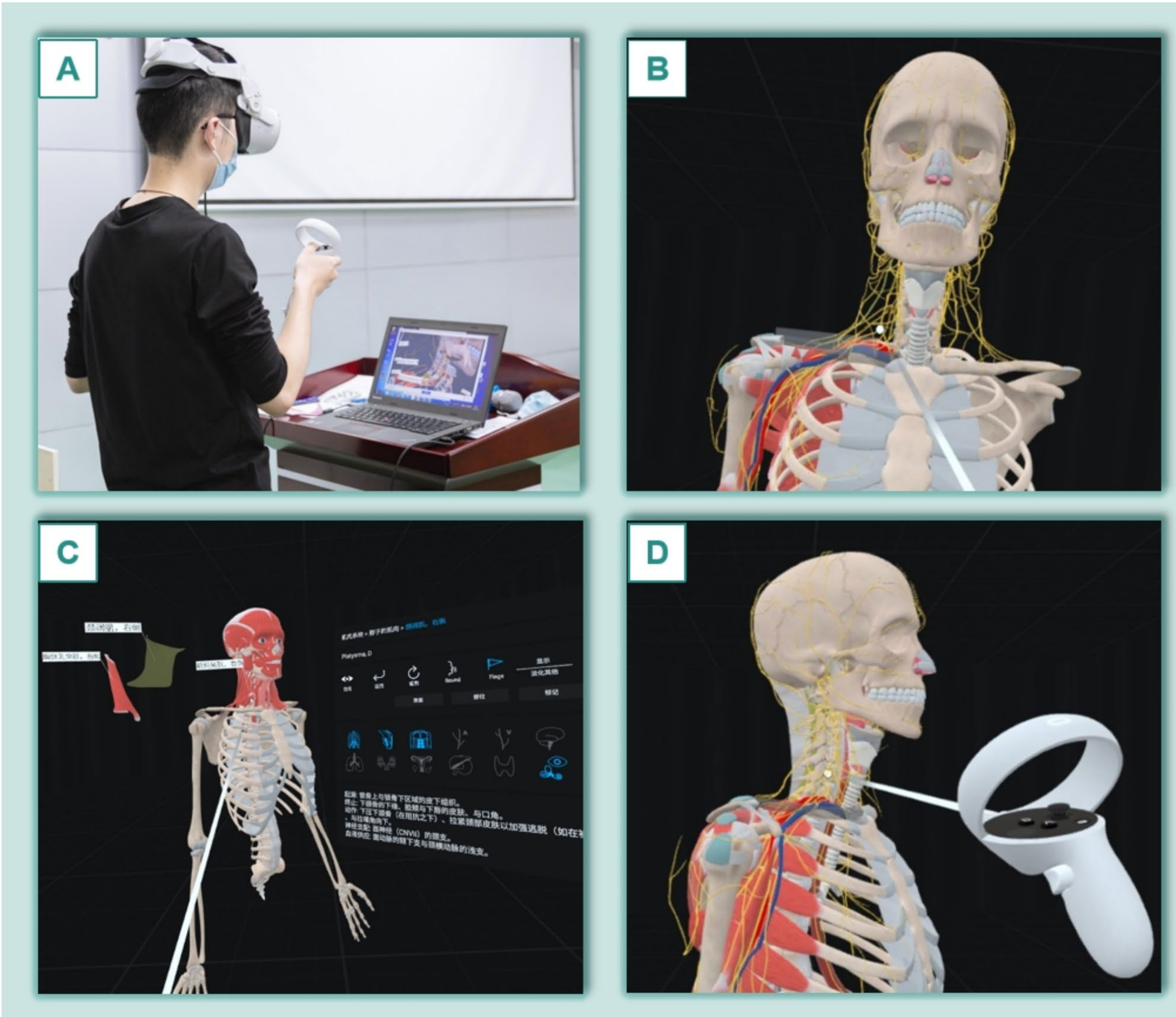


**Fig. 3** (**A**) An anesthesiology trainee learning the anatomy of brachial plexus through VR glasses and controllers (Oculus Quest 2); (**B**) (**C**) (**D**) Screenshots of anatomy learning of brachial plexus in 3D Organ Anatomy

images. A checklist of anatomical structures (Appendix A) was provided according to an international consensus on anatomical structures to identify on ultrasound for the performance of basic blocks in ultrasound-guided regional anesthesia [8]. Followingly, participants in both groups completed a 30-minute ultrasound-guided block practice on a nerve block model.

#### Materials and equipment

In this study, 3D Organon Anatomy® (Medis Media, Queensland, Australia) was used for anatomy training in the VR group. This software provides VR anatomical models within immersive environments combing with a 3D glass and offers the ability to transect anatomical models in any angle by a VR controller. The VR hardware used in this study was the Oculus Quest 2 headset and hand controllers (Oculus Rift®; Oculus VR, Irvine, CA). The anatomical region used for training was determined as the brachial plexus module and the neck region module in 3D Organ Anatomy. The ultrasonography equipment used in the study was the Sonosite SII (FUJIFILM Sonosite Inc.) The ultrasound-guided nerve block puncture training model (Ningbo Lancet Company) was constructed from an elastomeric tissue-mimicking material that facilitates needle insertion and ultrasonographic visualization. The model was equipped with four nerves, each with an internal diameter of 2–3 mm and a depth of 10–20 mm. The dimensions of the model are 150 mm* 120 mm*40 mm (length*width*height).

### Evaluation of performance

The outcomes were evaluated through a two-phase testing process (Fig. 2). The primary outcome was the trainees' performance during their initial ultrasound-guided interscalene brachial plexus block, assessed using both the Global Rating Scale (GRS) and a task-specific Checklist (see Appendix B). The improvement in scores for theoretical knowledge measured by written multiple-choice questions (MCQs) (see Appendix C) was the secondary outcome.

*Phase I: theoretical tests.* Participants completed written MCQs testing their knowledge of both anatomy and ultrasound before and after the theoretical course on ultrasound-guided brachial plexus block. The questions on both MCQs tests were based on the lecture. Two different tests, each with 20 questions, scores ranging from 0 to 100, were employed. The pre-test and post-test were compared separately between VG and CG. The score gains of both groups were compared as well. Both MCQs tests had previously been employed as part of UGNB training within our department. In this study, the pre-test and post-test of MCQs had difficulty indices of 0.5 and 0.57, and discrimination indices of 0.2 and 0.25, which were consistent with standard metrics for effective assessment design. The difficulty index (ranging from 0 to 1) represents the proportion of correct answers, with 0.5 indicating optimal difficulty. The discrimination index reflects a question's ability to differentiate between high- and low-performing participants, with values $\geq 0.2$ considered acceptable.

*Phase II: practical skills performance evaluation.* On the day following the training, all participants conducted a single ultrasound-guided interscalene brachial plexus block using in-plane technique on patients scheduled for shoulder or upper arm surgery under regional anesthesia combined with general anesthesia. Standard monitoring, oxygenation, and intravenous fluids were administered to each patient during the procedure. All trainees were allowed to proceed for a maximum of 30 min at the discretion of the supervisor (other than the expert evaluator), who was always present and intervened if (1) the patient became hemodynamically unstable, (2) the patient experienced paresthesia along the distribution of the brachial plexus, (3) if blood was noted on aspiration, or (4) if the procedure took longer than 30 min. Two onsite expert observers evaluated their performance using the 22-item procedural Checklist and a 9-item GRS [9]. The entire procedure took place in the operating theatre. The Checklist consisted of specific items that were graded either "0," not performed; "1," performed with prompting/ poorly performed; or "2," unprompted and performed. The GRS consisted of a 5-point scale, with 9 items related to preparation, patient care, and technical skills specific to ultrasound-guided regional anesthesia (UGRA). The 22-item checklist measured task completion and procedural accuracy, while the GRS evaluated overall performance quality across key domains. The full instruments are provided in Appendix B.

### Resource feedback

After the assessment, participants in VG were requested to complete a feedback questionnaire (see Appendix D for full details) independently, obtaining their opinions and feelings about the VR-assisted training program. The survey evaluated perceptions of the course's difficulty level and inquired about its capacity to engage learners' interest. Additionally, it gathered opinions on the program's effectiveness in enabling participants to master nerve block procedures.

### Statistical analysis

This pilot study focused on the feasibility of VR-based anatomy training for performing UGNB. The sample size, aimed at 10 participants per group, was chosen based on recommendations from the literature on medical education research [10] and not for statistical hypothesis testing.

The chi square and Fisher's exact test was used to compare the distribution of gender, types of trainees. Normal distribution was observed for age, pretest and post-test results, and test scores gains in both groups. Independent *t*-tests were used to evaluate scoring differences between two groups regarding to score gains, GRS and the Checklist. Paired *t*-test was employed to assess disparities between pre-test and post-test scores. A Mann-Whitney U test was used to compare the differences of self-evaluation of the anatomy level and spatial ability between two groups. $P<0.05$ indicated statistical significance. Statistical analysis was performed using SPSS Statistics Version 27.0 (IBM Corp, Armonk, NY).

## Results

### Study participants

We enrolled 21 novice trainees majoring anesthesiology in this study. Statistical analysis revealed no significant differences between the groups in terms of gender, age, seniority, self-reported anatomy knowledge, or spatial reasoning ability ($P>0.05$). Demographic details of the participants are presented in Table 1.

### Primary outcome

We compared UGNB performances between the VR group and the control group using the GRS and the task-specific Checklist for UGRA. No significant difference was found in GRS scores ($P>0.05$). However, the VR-trained group outperformed the control group on the Checklist, with mean scores of 29.23 (SD = 3.91) vs. 24.85

**Table 1** Baseline characteristics of 21 study participants

| | | VR group | Control group | *P* value |
|---|---|---|---|---|
| | | *N* = 11 | *N* = 10 | |
| Gender | | | | 0.505 |
| | Male | 6 (54.55%) | 4 (40.00%) | |
| | Female | 5 (45.45%) | 6 (60.00%) | |
| Age | | 26.27 ± 3.10 | 24.40 ± 1.58 | 0.102 |
| Seniority | | | | 0.525 |
| | Resident | 9 (81.82%) | 7 (70.00%) | |
| | Intern | 2 (18.18%) | 3 (30.00%) | |
| Self-evaluation of the level of anatomy knowledge | | | | 0.889 |
| | Excellent | 1 (9.09%) | 0 (0.00%) | |
| | Good | 2 (18.18%) | 2 (20.22%) | |
| | Average | 3 (27.27%) | 5 (50.00%) | |
| | Fair | 5 (45.45%) | 3 (30.00%) | |
| Self-evaluation of spatial reasoning | | | | 0.392 |
| | Excellent | 5 (45.45%) | 1 (10.005) | |
| | Good | 3 (27.27%) | 8 (80.00%) | |
| | Average | 2 (18.18%) | 0 (0.00%) | |
| | Fair | 1 (9.09%) | 1 (10.00%) | |

Values are presented as the number (%) of participants or the mean ± SD, unless indicated otherwise. *P* value < 0.05 represents a statistical difference between the two groups

**Table 2** The results of global rating scale and checklist

| | VR group (*N* = 11) | Control Group (*N* = 10) | t-test | *P* |
|---|---|---|---|---|
| GRS | 30.91 ± 7.03 | 29.00 ± 5.98 | 0.667 | 0.513 |
| Checklist | 29.23 ± 3.91 | 24.85 ± 5.13 | 2.212 | 0.039* |

Values are presented as the mean ± SD. **P* value < 0.05 represents a statistical difference between the two groups

**Table 3** Comparison of pre-test, post-test and score gains between the VR and control groups

| | VR Group (*N* = 11) | Control Group (*N* = 10) | t | *P* |
|---|---|---|---|---|
| Pre-test | 57.27 ± 17.94 | 57.00 ± 11.11 | 0.041 | 0.967 |
| Post-test | 79.09 ± 10.68* | 78.00 ± 6.75* | 0.276 | 0.785 |
| Score gains | 21.82 ± 12.30 | 18.33 ± 9.68 | 0.691 | 0.498 |

Values are presented as the mean ± SD, *represents a statistical difference between the pre-test and the post-test for within-group comparisons

(SD = 5.13), respectively, indicating significantly better proficiency ($P < 0.05$). (Table 2).

### Secondary outcome

All study participants completed MCQ tests before and after the theory course. The results showed that both groups had similar scores before the course, and both groups improved their scores after the theory course ($P < 0.001$). There was no significant difference in score gains between the two groups. ($P > 0.05$). (Table 3)

### Results of the feedback questionnaire

Based on the feedback questionnaire, 45.5% of respondents found it easy to operate the VR equipment, only one found it difficult. Most participants (72.7%) found VR helpful in understanding the anatomy of the brachial plexus and its spatial structure. In addition, 81.8% thought it helpful in learning ultrasound-guided nerve block techniques. Nevertheless, all participants experienced some degree of discomfort with the VR view, ranging from mild (ten participants) to severe (one participant). (Table 4)

## Discussion

We designed this pilot study to investigate the feasibility and the effect of VR-assisted anatomy teaching on the acquisition of the skill of ultrasound-guided interscalene brachial plexus block by novice learners. Our study suggests that VR-assisted anatomy teaching could be beneficial for novices in acquiring UGRA block skills than the traditional multimedia instruction curriculum during the training of anesthesia skills.

Mastery of the skill of UGRA requires not only the memorization of anatomical structures, but also a comprehension of the 3-D interrelations among adjacent anatomical entities, which is integral for the precise interpretation of ultrasonographic images. Immersive VR technology can provide learners with a more vivid, intuitive, and immersive learning experience, thus facilitating spatial comprehension and concentration in learning. To the best of our knowledge, there is a strong correlation between spatial ability and hands-on skills. As is stated by Keehner et al. [11], spatial ability was associated with the performance of laparoscopic skills in the lower experienced group. Hu et al. [7] also found that VR-integrated anatomy training could enhance the learning of ultrasonography skills in novice learners.

The Global Rating Scale and UGRA-specific checklist were developed by Cheung et al. [9], in order to assess UGRA skill performance in an objective manner. The structural validity of the GRS and the Checklist has

**Table 4** Trainees' feedback of the VR-assisted anatomy learning in UGNB training

| Questions Regarding the VR anatomy learning | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Easy to use VR device | | 1 (9.1%) | 5 (45.5%) | 5 (45.5%) | |
| Helpful for understanding anatomy | | 1 (9.1%) | 2 (18.2%) | 7 (63.6%) | 1 (9.1%) |
| Helpful for acquiring UGNB | | | 2 (18.2%) | 4 (36.4%) | 5 (45.5%) |
| Uncomfortable with VR | | | | 10 (90.9%) | 1 (9.1%) |
| Increasing interest in learning | | | | 1 (9.1%) | 10 (90.9%) |

Values were presented as the number (%) of participants been verified in clinical settings by Laurent et al. [10]. Notably, the GRS demonstrated discriminative capability in distinguishing between novice and experienced anesthesia practitioners. Our research aimed to assess the performances of trainees undertaking ultrasound-guided interscalene brachial plexus blocks. Interestingly, comparisons of GRS outcomes yielded no statistically significant differences between the VR-assisted and conventional training modalities. This suggests that both training approaches are comparable in their effectiveness, as measured by the GRS. In contrast to the GRS results, the results of Checklist revealed that participants receiving VR-based instruction exhibited markedly enhanced performance, achieving significantly higher scores than their counterparts trained through traditional methods. This discrepancy between the GRS and Checklist outcomes may be instructive. According to the content, the Global Rating Scale measures comprehensive skill aspects in performing ultrasound-guided nerve blocks, such as speed and fluency, which can be challenging for novice learners to master. In contrast, the Checklist provides a more detailed evaluation of specific procedural elements. This discrepancy may explain why no significant difference in GRS was observed between the two groups. Overall, we observed a slightly better skill performance in the VR group, which may be attributed to the role of VR in enhancing the understanding of spatial anatomical structures. However, our study could not rule out the possibility of pre-existing differences in skill learning ability between the two groups.

In our investigation, we observed that the integration of VR into anatomy courses did not yield statistically significant improvements in theoretical test scores over traditional teaching methods. This indicates that the effectiveness of VR-based instruction parallels that of conventional multimedia-based pedagogy in imparting knowledge of ultrasound and anatomy. This result is consistent with several previous studies. Ellington et al. [12] noted that residents exposed to the VR anatomic model showed similar score gains with those trained with non-VR curriculum for pelvic anatomy, regardless of their year of training. Stepan et al. [13] examined the impact of immersive VR on the neuroanatomy knowledge of medical students by comparing with online textbooks, and no significant difference was found in neuroanatomy knowledge between the two groups on pre-intervention, post-intervention and retention quizzes. This parity in outcomes of theoretical tests may be attributed to the short interval between the lecturing and the MCQ tests, indicating that the immersive nature of VR learning may not exert a pronounced effect on short-term memory retention. Prior research has suggested that engagement in immersive VR environments can facilitate enhanced exploration of anatomical structures, bolstering memory consolidation and comprehension, thereby fostering long-term retention of anatomy knowledge [14]. In addition, the nature of the MCQs, which predominantly require rote memorization rather than deep comprehension, may result in a lack of discernible distinction between the two groups. We argue that VR-based training provides an opportunity to transition from rote memorization—defined as the repetition-based retention of facts without meaningful understanding—toward deep comprehension, which involves the integration of new knowledge into existing frameworks, fostering a practical and meaningful understanding of UGNB anatomy.

As evidenced by previous studies, medical students or trainees have expressed positivity towards the effectiveness of VR technology in teaching anatomy and skills training [2, 15, 16]. Participants found the VR-assisted anatomy curriculum engaging and conducive to a deeper understanding of anatomical concepts, echoing the sentiments reported by Ramlogan et al. [15], which highlighted the near-unanimous appreciation for VR's utility in learning spinal anesthesia through simulation. However, our study also identified drawbacks associated with VR usage: physical discomfort with the VR view. A trainee in our study experienced significant feelings of dizziness and nausea, suggesting a need for careful integration of VR technology into medical education to maximize its potential while safeguarding learner well-being.

This study has several limitations. First, we recognize that the duration of the VR intervention may have been too short to demonstrate a substantial effect on learning outcomes. Prolonged and repeated exposure to VR-based training might yield more pronounced differences between groups. Second, the administration of the theory test shortly after the lectures may have minimized the variance in theoretical scores between the VR group and traditional groups, as the intensive learning environment likely equalized immediate retention across all participants. Third, reliance on participants' subjective self-assessment of their anatomy understanding and spatial skills introduces an element of bias that may not accurately reflect the actual differences between the groups. Additionally, as a pilot study, the sample size, was relatively small, resulting in higher than anticipated standard errors in GRS and Checklist scores. Future research of randomized controlled trials comparing VR teaching directly to traditional anatomy teaching would provide stronger evidence.

## Conclusions

This preliminary study indicates that virtual reality anatomy training has the potential to enhance the technical proficiency of novice anesthesiologists performing ultrasound-guided interscalene brachial plexus blocks, as evidenced by improved Checklist scores.

Additionally, trainees demonstrated a clear preference for the VR-assisted curriculum, perceiving it as beneficial for mastering anatomical knowledge and UGNB skills. It is anticipated that VR will emerge as a prominent and appealing tool in the training program of anesthesia techniques in the future.

#### Abbreviations

| | |
|---|---|
| 2D | Bidimensional |
| 3D | Three-dimensional |
| CG | Control group |
| GRS | Global Rating Scale |
| HMDs | Head-mounted displays |
| MCQs | Multiple-choice questions |
| UGNB | Ultrasound-guided nerve block |
| UGRA | Ultrasound-guided regional anesthesia |
| VG | VR group |
| VR | Virtual reality |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-024-02865-3.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

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Not applicable.

#### Author contributions
XYL, JPC and BL contributed to the conception and design of the study. SQY and QS collected and analyzed the data. SQY, ECL and XJA contributed to the investigation and the study methodology. XZX and YL prepared the resources. XYL and JLQ drafted the manuscript. BL made critical revisions of the manuscript. All authors reviewed the manuscript.

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#### Data availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

#### Ethics approval and consent to participate
The study has been conducted in accordance with the principles set forth in the Helsinki Declaration. Written informed consent was obtained from the participants and patients in this study. This study conforms to the CONSORT guidelines.
Ethical approval for this study (Approval NO.SL-NBEY-KY-2022-061-01) was provided by the Clinical Research Ethics Committee of the Ningbo No.2 Hospital, Haishu District, Ningbo City, Zhejiang Province on 01/04/2022.

#### Consent for publication
Not applicable.

#### Competing interests
The authors declare no competing interests.

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