Journal of Clinical Anesthesia 48 (2018) 22–27

Contents lists available at ScienceDirect

Journal of Clinical Anesthesia

journal homepage: www.elsevier.com/locate/jclinane

Original Contribution

# Deliberate practice using validated metrics improves skill acquisition in performance of ultrasound-guided peripheral nerve block in a simulated setting

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ARTICLE INFO

*Keywords:*
Deliberate practice
Metrics
Procedural skills

ABSTRACT

*Study objectives:* The aim of this study was to compare the effects of deliberate vs. self-guided practices (both using validated metrics) on the acquisition of needling skills by novice learners.
*Design:* Randomized Controlled Study.
*Setting:* Simulation lab, Department of Anesthesia, St.Vincent's Hospital, Dublin.
*Subjects:* Eighteen medical students.
*Interventions:* Students were assigned to either (i) deliberate practice ($n = 10$) or (ii) self-guided practice ($n = 8$) groups. After completion of a 'learning phase', subjects attempted to perform a predefined task, which entailed advancing a needle towards a target on a phantom gel under ultrasound guidance. Subsequently, all subjects practiced this task using predefined metrics. Only subjects in the deliberate practice group had an expert anesthesiologist during practice. Immediately after completing 'practice phase', all subjects attempted to perform the same task, and, on the following day, made two further attempts in succession. Two trained consultant anesthesiologists assessed a video of each performance independently using the pre-defined metrics.
*Measurements:* Number of procedural steps completed and number of errors made.
*Main results:* Compared with novices who self-guided their practice using metrics, those who undertook expert-supervised deliberate practice using metrics completed more steps (performance metrics) immediately after practice (median [range], 14.5 [12–15] vs. 3 [1–10], $p < 0.0001$) and 24 h later (15 [12–15] vs. 4.5 [1–11], $p < 0.0001$ and 15 [11–15] vs. 4 [2–14], $p < 0.0001$). They also made fewer errors immediately after practice (median [range], 0 [0–0] vs. 5 [3–8], $p < 0.0001$) and 24 h later, (0 [0–3] vs. 6.5 [3–8], $p < 0.0001$ and 0 [0–3] vs. 4 [2–7], $p < 0.0001$).
*Conclusion:* Combining deliberate practice with metrics improved acquisition of needling skills.

## 1. Introduction

Safe performance of ultrasound-guided peripheral nerve blocks (PNB) requires competence across a range of technical and non-technical skills [1]. Correct placement of a needle close to a nerve or plexus is critical to safe and successful procedure performance [2]. Failure to maintain needle visibility while in forward motion may cause iatrogenic injury to nerves and surrounding structures, and is a 'quality compromising' behavior in the early part of novice learning curve [3,4]. Skills related to needle guidance are difficult to learn, as they require integration of multiple cognitive and psychomotor elements. This may impose a daunting challenge on novice learners. To learn these skills, trainees currently depend on the traditional apprenticeship model of learning usually supplemented by lectures, courses and online materials. Trainees have access to a variety of commercially available phantoms (tissue and gelatin) to practice their skills [5,6]. Other investigators have reported the use of simulators and needle guidance systems to teach needling skills [7–9]; however the efficacy of these approaches in terms of validation and meaningful outcomes is not widely accepted [10]. Previously, surgical disciplines used metrics-

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https://doi.org/10.1016/j.jclinane.2018.04.015
Received 17 February 2018; Received in revised form 13 April 2018; Accepted 27 April 2018
0952-8180/ 

based deliberate practice integrated on simulated platforms to train procedural skill acquisition. This approach facilitates learning; objectively assess training progress and the resultant enhanced performance transfers to clinical practice [11–14]. 'Deliberate practice' as introduced by Ericsson [15] is a focused approach to skill training, highly structured and set to achieve a well-defined goal. In contrast to repeated practice, implementation of deliberate practice is based on certain design principles: (i) repeated performance of intended skill (ii) rigorous assessment of skill performance and (iii) real time formative feedback. Training is deemed to be adequate when the skill is learned, demonstrated competently and assessed satisfactorily by a trainer [15,16]. If deliberate practice using metrics consistently works for procedural skills in surgical disciplines why did Udani et al. [17] find no effect at one day and at three months when applied to acquisition of ultrasound-guided regional anesthesia skills? We propose that deliberate practice should be integrated with validated metrics. Care taken to develop and validate metrics meticulously is rewarded with (i) improved performance when incorporated into a training curriculum and (ii) improved objectivity in the assessment process. We hypothesized that combining deliberate practice with valid procedure characterization (metrics) [18,19] improves needling skills of novices performing simulated ultrasound guided needle advancement for regional anesthesia procedures. The objective of this study was to compare the effects of expert-supervised deliberate practice vs. self-guided practice (when both using metrics) on novice needling skill acquisition.

## 2. Materials and methods

The study was approved by the Ethics and Medical Research Committee of St.Vincent's Healthcare Group, Elm Park, Dublin 4, Ireland. The study is registered in ClinicalTrials.gov under the number: NCT03154372.

Having obtained informed written consent from each, eighteen 3rd and 4th year medical students from University College Dublin (UCD), Ireland with no previous experience of ultrasound-guided procedures were recruited. Each student provided demographic information on his or her age, gender and handedness. They underwent standard testing of their visuospatial and perceptual abilities (map planning, cube comparisons and card rotation) [20]. All subjects attended a didactic lecture (learning phase) delivered in a standard fashion by one investigator (OA). This included outlines of ultrasound physics, scanning and practical techniques. The skills required to guide a needle through a phantom under ultrasound guidance were demonstrated using a pre-defined list of metrics (Table 1) that is extracted from a previously validated procedure characterization [18,19].

Subsequently, subjects were randomly allocated using computer generated random numbers (that was retrieved from an investigator just before each subject commenced task performance) to one of two groups; self-guided practice (SP, n = 8) and expert-supervised deliberate practice (DP, n = 10). Approximately 24 h after completion of the learning phase each subject attempted to perform the following set of tasks (baseline assessment).

Task description:

(i.) Perform ultrasonography of the phantom (Regional Anesthesia Ultrasound Training Block Model, CAE blue phantom™, CAE Healthcare, www.bluephantom.com) provided to identify embedded objects (Fig. 1) as if preparing to perform nerve block.
(ii.) Identify verbally different objects in the ultrasound image (simulating sono-anatomy) in reference to the ultrasound training block model (Fig. 1).
(iii.) Once the ultrasound image is deemed optimal, advance a 50 mm, 20 gauge block needle provided (Stimuplex® Ultra 360®, B. Braun, Melsungen AG, Melsungen, Germany) under ultrasound guidance towards the object at the 4 O'clock position (Fig. 1).
(iv.) Once the needle tip is deemed close enough to the object, inject 0.5 ml of saline.

**Table 1**
Brief summary and abbreviated definitions of Metrics (Steps and Errors).

| Steps |
|---|
| 1) The operator checks the sidedness of the probe by touching the probe footprint with gloved finger or item such as needle cover |
| 2) The operator applies couplant over the ultrasound probe |
| 3) The operator holds the probe in a tripod grip |
| 4) The operator confirms the identity of the vessels (artery/veins) by performing the following discrete subtasks: |
| a. Presence of visually identifiable circular black structure |
| b. The application of pressure via the ultrasound probe confirming a non-compressible/compressible vascular structure |
| 5) The operator immobilizes the probe and scanning hand to provide a stable optimized image |
| 6) The operator verbally identifies and points out on the screen the identity of the blood vessels |
| 7) The operator verbally identifies and points out on the screen the target structure prior to needle insertion |
| 8) The operator flushes a 50 mm block needle with saline to expel all air |
| 9) The operator advances the block needle through an insertion point immediately adjacent to the midpoint of the upper border of the ultrasound probe (< 1.0 cm from the probe) |
| 10) The operator moves the needle forward when the needle tip and a portion of the distal needle shaft are visible |
| 11) The operator moves the ultrasound probe (PART maneuver) to find the needle tip and distal portion of the needle shaft |
| 12) On taking corrective probe movements, should the needle fail to be visualized, the operator withdraws the needle towards skin to reevaluates needle probe alignment |
| 13) The operator aspirates using a syringe prior to injection of test dose and/or block dose at target |
| 14) The operator uses a test dose of 0.5–1 ml of local anaesthetic to confirm needle tip |
| 15) Operator places full block dose (2mls) if the injectate is visualized adjacent to and in contact with the nerve surface area following test dose placement |

| Errors |
|---|
| 1) Operator advances block needle other than on the middle of the upper border of the ultrasound probe and other than in-plane to ultrasound beam |
| 2) Operator fails to keep needle tip and distal part of needle shaft in view when the needle in forward motion |
| 3) Operator continues to advance needle towards target without tip being visible |
| 4) Should the needle visibility lost, operator moves the needle and not the probe to find the needle tip and/or needle shaft |
| 5) Operator makes multiple needle redirections without tip being visible |
| 6) Operator makes multiple skin punctures using the block needle |
| 7) Operator does not aspirate prior to injection of test dose and/or block dose |
| 8) Operator continues to inject despite ultrasonographic evidence of injectate spreading away from the vicinity of the nerve |
| 9) Operator places the block needle inside the target structure |

Following the first set of tasks (baseline assessment), all subjects were allowed to practice the task using the list of metrics and according to their random group allocation.

### 2.1. Methods of practice were as follows

#### 2.1.1. SP group (n = 8)

An investigator provided subjects in this group the list of metrics; steps and errors (Table 1) and they were allowed to practice the task using these metrics. There was no expert supervision available for this group. When a participant declared readiness to progress to the assessment, training was deemed complete. The maximum time allowed for practice was 1 h.

#### 2.1.2. DP group (n = 10)

One trained consultant anesthesiologist (expert in ultrasound-guided PNB and who regularly undertakes training of novices in these procedures) supervised deliberate practice to each subject in this group