

Comprehensive Curriculum for Phantom-Based Training of Ultrasound-Guided Intercostal Nerve and Stellate Ganglion Blocks

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Abstract

Objective. Ultrasound (US)-guided pain procedures become increasingly important due to their numerous advantages. Solid proficiency is necessary, however, to minimize complications and guarantee adequate performance. To enable beginners to learn the relevant skills in the technique of US-guided stellate ganglion (SGB) and intercostal nerve block (ICB), a training curriculum was developed and tested using self-made phantoms.

Design. The curriculum comprised an introduction to the didactics of US, SGB, and ICB, a demonstra-

tion of the techniques by an expert user, as well as hands-on training of needle guidance using a gel pad and two phantoms.

Subjects. Three groups of participants with different levels of expertise with US-guided procedures took part in the curriculum: 12 medical students with no prior experience, 12 anesthesiologists with some experience, and five senior anesthesiologists who already applied these techniques on a regular basis.

Methods. Participants evaluated the curriculum via questionnaire, and their performance of time until adequate puncture, attempts required for adequate puncture, number of corrections, and unintentional punctures was assessed.

Results. The medical students significantly increased their speed during both nerve blocks and reduced the number of attempts and corrections necessary to perform adequate ICB. The anesthesiologists with some experience also increased their speed in both blocks. The participants rated the curriculum as good to very good.

Conclusions. The combination of theoretical teaching, expert demonstration, and hands-on training on phantoms proved useful in acquiring skills needed for US-guided procedures such as SGB and ICB, and can potentially improve graduate and post-graduate medical education.

Key Words. Ultrasound; Phantoms; Pain Management; Nerve Blocks; Training; Education

Introduction

Over the past years, ultrasound (US) guidance in pain procedures has gained increasing importance. Nonetheless, it is almost exclusively performed in specialized pain centers [1], possibly due to high demands for the operator. Compared with conventional techniques (e.g., landmark based, fluoroscopy), US guidance has numerous advantages [2,3] and may lead to fewer complications because structures at risk (e.g., blood vessels, organs) become identifiable and needle contact can be avoided [1,4]. The

onset time of the nerve blocks is shorter on average, while the quality is the same or even improved [1,4–6]. Despite the increasing use of US in pain management, effective means of training physicians in those methods are still lacking, and the handling of US is infrequently part of the teaching curriculum in medical schools [7]. Yet, profound knowledge and experience in US-guided techniques are crucial for their safe administration and success [2,8]: Operators should understand the technical background, be able to identify anatomical structures using US, and know how to coordinate US transducer and needle.

Phantom-based hands-on training can provide an optimal setting to acquire and practice the skills needed for US-guided procedures without posing a threat to the patients' health and safety. It can lead to steeper learning curves, increase the operator's confidence and puncture speed, and reduce the number of mistakes made [9–12]. Unfortunately, most physicians have no access to phantom-based training as it is often expensive, and the training phantoms which simulate the specific anatomical condition during individual nerve blocks *in situ* are scarce.

US-guided intercostal nerve (ICB) and stellate ganglion blocks (SGB) are important procedures in pain management with an intermediate level of difficulty [2]. Indications for ICB are acute or post-herpetic neuralgia or post-thoracotomy syndrome. SGB is used to treat sympathetically maintained pain of the upper extremity, for example in complex regional pain syndrome. Evidence shows that US guidance may improve performance, efficacy, and safety in these procedures compared with conventional techniques [3]. Here, we present to our knowledge the first comprehensive teaching curriculum for ultrasound-guided SGB and ICB using self-assembled phantom models.

The aim of this study was to 1) to evaluate the easily applicable curriculum and assess its value in improving inexperienced participants' performance of the nerve blocks, and 2) to validate the usability of our self-assembled phantoms. It is hypothesized that particularly, the less experienced users will benefit from the training tool allowing them to acquire the procedural skills to perform the nerve blocks on phantoms.

Materials and Methods

Participants

Twenty-nine participants took part in the curriculum after giving verbal informed consent. These subjects were then allocated into one of three groups: medical students (N = 12, 8 females) without prior experience in US-guided procedures ("beginners"), anesthesiologists (N = 12, 4 females) with some experience in US-guided procedures (e.g., regional anesthesia, vessel puncture; "experienced"), and anesthesiologists (N = 5, 1 female) with at least 3 years of routine in performing US-guided SGB and ICB on a regular basis ("experts"). After consulting with the

local ethics committee, we abstained from applying for IRB approval for this study, since we did not collect or store personal data on the participants.

The Phantoms

Three reusable phantoms were built. The gel used for the phantoms was made of a mixture from guar gum with borate. The preparation of the gel took 1 to 2 hours, after which it was stored in the refrigerator overnight to eliminate bubbles.

A small metal bowl filled with the gel was used as a phantom for training needle coordination. To provide targets for the training of handling US probe and needle simultaneously, a "bone" made of plaster and a water-filled latex tube serving as "vessels" were incorporated.

For the SGB phantom (Figure 1A–C), a wire box (5 × 4 centimeters) was fitted with three casted vertebrae made of plaster (original models of human vertebra 5 through 7 from a plastic model of the spinal column). A latex cast of a spiral garden hose was used as a surrogate trachea. The vessels (carotid artery, jugular vein) were casted using latex milk and filled with water. The guar gum gel was filled into this container (showing a depth of 3 centimeters, please refer to Figure 1C) to simulate thyroid and muscle tissue, especially the longus colli muscle that ordinarily would be the target in SGB. However, we were not able to mimic the fascia of the longus colli muscle, and therefore the penetration of the fascia could not be simulated. We hence decided to use bone contact of the transverse process as a surrogate for a successful attempt of SGB. The box was placed in a plastic mold, simulating the configuration of the neck.

The ICB phantom (Figure 2A–C) was constructed similarly in a 5 by 10 centimeters wire box. Five "ribs" (pork ribs molded in clay) were arranged parallel with a margin of one centimeter between them. Spanning the entire container, a latex membrane "pleura" with approximately one millimeter thickness was placed beneath the casted ribs. The gel was then filled into the margins and above the ribs in approximately one centimeter thickness. Intercostal tissue was simulated with the gel using varying consistencies. All phantoms were sealed with latex membranes.

The costs of each phantom add up to approximately 100 €.

Technical Equipment

For US, a Siemens Acuson X150 (Düsseldorf, Germany) with the linear US probe VF 13-5 (7.5 to 11 MHz) was used. Needle puncture was performed with disposable 25-gauge steel cannulae. The correct position of the cannula during ICB was verified by visually injecting 0.5 mL of 0.9% saline solution. The correct position of the cannula during SGB was reached upon "bone" contact.

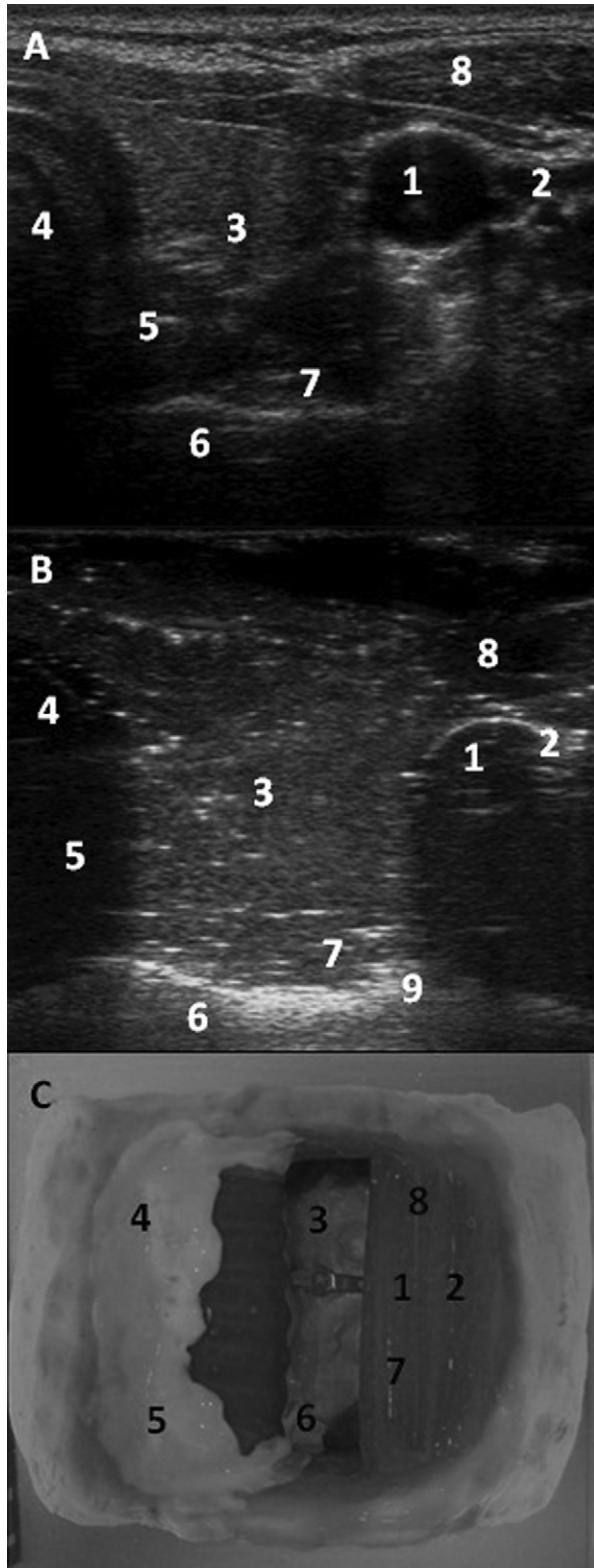


Figure 1 Ultrasound image of the in-vivo anatomy of the neck (A), compared with the training phantom for the stellate ganglion block (SGB) (B), and the photograph of the SGB phantom (C).

Captions: 1, common carotid artery; 2, internal jugular vein; 3, thyroid gland; 4, trachea; 5, esophagus; 6, transverse process of sixth cervical vertebra; 7, longus colli muscle; 8, sternocleidomastoid muscle, 9, anterior tubercle.

The Curriculum

The content of the curriculum was made up of five sections: 1) Didactics: An automated slideshow presentation with audio recordings (duration: 15 minutes) introduced participants to basic principles of US imaging, in-plane and out-of-plane approaches, US probe, indication, relevant anatomical structures, possible adverse events, and performance of the nerve blocks. Two videos showing the nerve blocks in a real patient in real time were embedded to illustrate the anatomy behind the US image; 2) Demonstration: Initially, an experienced user of US-guided pain procedures demonstrated the handling of the US probe and the imaging in vivo. Then, he introduced the participants to the usage of the phantoms (duration: max. 15 minutes); 3) Training of needle-coordination: The participants trained their hand-eye coordination by simultaneously handling the needle and the US probe on the phantom for five minutes; 4) One block with supervision: SGB and ICB were performed on the phantoms with the out-of-plane approach. The first nerve block was performed assisted by an expert instructor, and participants were allowed to ask questions; 5) Performance without assistance: At the end of the training, the participants filled out a form in order to evaluate the curriculum, the phantoms, and their assumed training success.

Data Acquisition and Statistical Analysis

During performance testing, four dependent variables were assessed: 1) Time to reach the target (bone contact for SGB, correct needle position verified by injection of saline for ICB); 2) Number of attempts needed (an attempt was defined as new puncture of the skin); 3) Number of corrections made (retraction of the cannula); 4) Number of unintentional injuries of trachea or blood vessels (SGB) and ribs or pleura (ICB). Because of the expert's assistance, the first out of five performed nerve blocks was not counted for the analyses. The evaluation questionnaire consisted of 19 questions (Table 1). Participants were asked to respond on a scale from 1 (*excellent*) to 6 (*unsatisfactory*), and they were allowed to comment on the curriculum, if desired.

Statistical analyses were performed with IBM SPSS Statistics Version 20.0 (Armonk, NY, USA). As Shapiro–Wilk

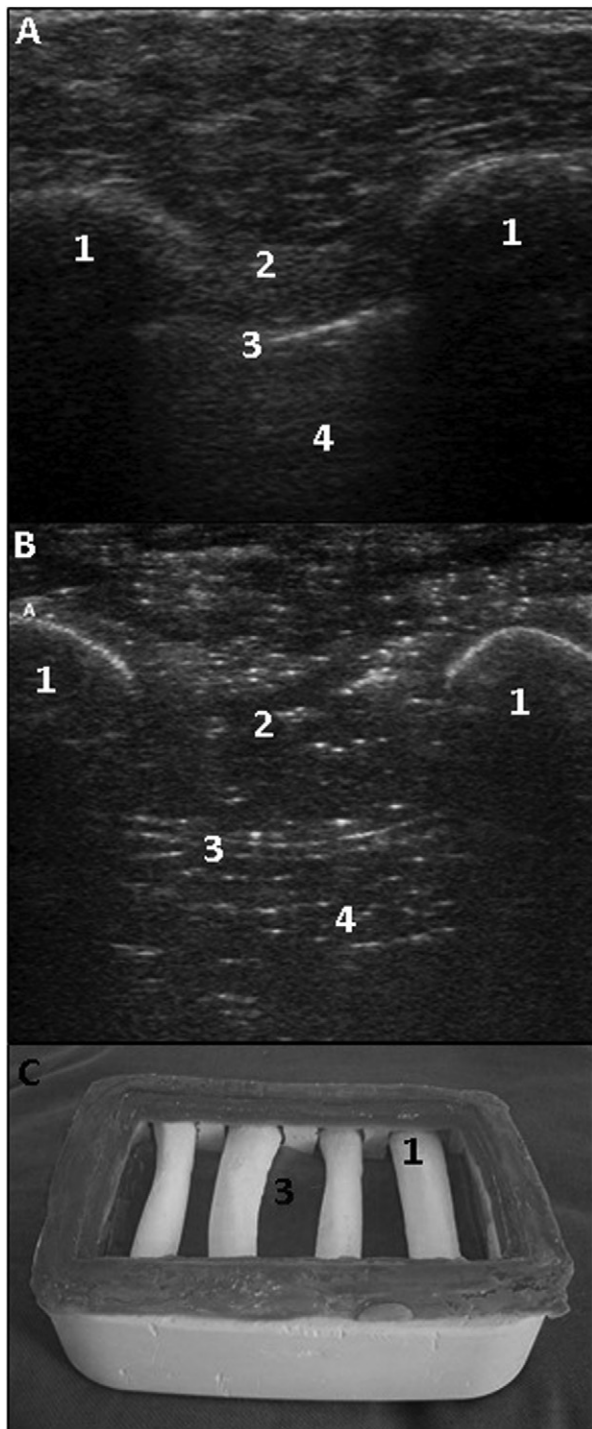


Figure 2 Ultrasound image of the in-vivo anatomy of the thorax (A), compared with the training phantom for the intercostal nerve block (ICB) (B), and the photograph of the ICB phantom (C). Captions: 1, ribs; 2, layers of intercostal muscles; 3, pleura; 4, lung.

testing indicated that the data were not normally distributed, nonparametrical tests were applied. The Friedman test was used to analyze changes of the dependent variables within each group across the four nerve blocks. To test for differences between the three groups of participants, the Kruskal–Wallis test was used. Wilcoxon signed-rank and Mann–Whitney *U*-tests served as post-hoc tests, where applicable. The alpha level was set to 5%.

Results

Intercostal Nerve Block (ICB)

Time to Reach the Target

The three groups differed in the time needed to perform the ICB ($H = 29.1$, $P < 0.001$). Post-hoc comparisons showed that beginners were slower than the experienced in the second block by trend (Figure 3A; $U = 42$, $P = 0.089$) and in the fifth block ($U = 33.5$, $P = 0.024$). Moreover, they were slower than the experts in all blocks ($U = 0$, $P < 0.001$; $U = 3$, $P = 0.002$; $U = 4$, $P = 0.004$, $U = 9$, $P = 0.027$). The experienced and the expert group did not differ on single nerve blocks.

The beginners (FR = 15.5, $P = 0.001$) and, by trend, the experienced (FR = 7.3, $P = 0.064$), increased their speed across the four ICBs (Figure 3A). The beginners achieved an average time reduction of 53.1%, the experienced reduced their required time by 46.8%. The experts did not increase their speed significantly (FR = 3.8, $P = 0.29$).

Number of Attempts Needed to Reach the Target

Overall, the three groups did not differ in the number of attempts needed to perform the ICB ($H = 3.8$, $P = 0.147$).

Within groups, only the beginners' required number of attempts decreased by trend across the four analyzed nerve blocks (from $M = 1.7$ to $M = 1.3$ attempts; FR = 6.3, $P = 0.098$; Figure 4A).

Number of Corrections Made

The number of corrections differed between the three groups ($H = 14.7$, $P = 0.001$). Post-hoc tests revealed that beginners made more corrections during the second nerve block compared with the experts ($U = 9.5$, $P = 0.027$).

Also, only the beginners significantly improved over time (from $M = 1.7$ to $M = 0.7$ corrections; FR = 10.6, $P = 0.014$; Figure 5A).

Unintentional Punctures

The three groups differed in the number of unintentional punctures of the pleura ($H = 8.1$, $P = 0.017$). The experienced punctured the pleura more often ($M = 1.3$, $SD = 1.15$) than the experts ($M = 0$, $SD = 0$; $U = 103$, $P = 0.078$) and, by trend, the beginners ($M = 0.6$,

Table 1 Evaluation of the curriculum. The participants (N = 29) were asked to rate questions on a scale from 1 (*excellent*) to 6 (*unsatisfactory*)

Question No.	M	SD
Introduction (presentation)		
1. Topical scope	1.4	0.62
2. Length of time	1.5	0.57
3. Comprehensibility	1.3	0.46
4. Quality of the preparation for the practical part	1.3	0.47
5. Grade for the whole introduction	1.3	0.55
Demonstrations on the patient and on the phantoms		
6. Topical scope	1.4	0.68
7. Length of time	1.4	0.73
8. Comprehensibility	1.3	0.61
9. Quality of the preparation for the practical part	1.4	0.57
10. Grade for the whole demonstration	1.3	0.53
Practical part (practicing on phantoms)		
11. Topical scope	1.3	0.72
12. Length of time	1.3	0.53
13. Veridicality of the phantoms, compared with human ultrasound	2.2	1.06
14. Handling of the phantoms	1.6	0.78
15. Grade for the whole practical part	1.5	0.83
Integrated concept		
16. Please evaluate your personal learning success.	1.8	0.79
17. Please rate the applicability in the clinical practice of what you have learned.	1.8	0.91
18. Please assess the curriculum in comparison to the usual training (i.e., watching an experienced operator and then directly carrying out the task in a patient).	1.5*	0.91
19. Please evaluate the general utilization of phantoms for educational training.	1.3	0.65

* Significant comparison between experienced and beginners ($P < 0.05$), please refer to results section for details.
M = mean; SD = standard deviation.

SD = 1.08; $U = 7.5$, $P = 0.014$). No difference between the three groups was detected concerning unintentional punctures of the ribs ($H = 0.09$, $P = 0.958$; beginners: M = 0.3, SD = 0.45; experienced: M = 0.3, SD = 0.65; experts: M = 0.2, SD = 0.45).

Stellate Ganglion Block (SGB)

Time to Reach the Target

The three groups differed in the time needed to perform the SGB ($H = 19.1$, $P < 0.001$). Post-hoc tests showed that beginners were slower than the experienced in the second ($U = 36.5$, $P = 0.039$) and fifth block ($U = 35$, $P = 0.033$) and slower than the experts in the second ($U = 9$, $P = 0.027$) and third block ($U = 11$, $P = 0.048$). The experienced and the experts did not differ according to the post-hoc tests.

The beginners (FR = 10.1, $P = 0.018$) and the experienced (FR = 16.5, $P = 0.001$) significantly increased their speed during the four analyzed nerve blocks (Figure 3B) and reduced the time needed by 58.8% (beginners) and, respectively by 52% (experienced). The speed performed by the experts did not change over all four interventions (FR = 0.48, $P = 0.924$).

Number of Attempts Needed to Reach the Target

The groups did not differ in the number of attempts needed to perform the nerve block (Figure 4B; $H = 3.7$, $P = 0.155$), and the number of attempts remained constant over time in all groups (beginners: FR = 2.23, $P = 0.525$; experienced: FR = 1.32, $P = 0.724$; experts: FR = 3; $P = 0.392$).

Number of Corrections Made

The groups did not differ in the number of corrections needed (Figure 5B; $H = 3.4$, $P = 0.187$).

None of the groups showed a significant reduction of corrections across all four attempts (beginners: FR = 2.44, $P = 0.486$; experienced: FR = 3, $P = 0.392$; experts: FR = 3.67; $P = 0.3$).

Unintentional Punctures

No difference between groups could be detected concerning unintentional punctures of the trachea ($H = 2.2$, $P = 0.333$; beginners: M = 0.2, SD = 0.39; experienced: M = 0.5, SD = 0.67; experts: M = 0.2, SD = 0.45) and

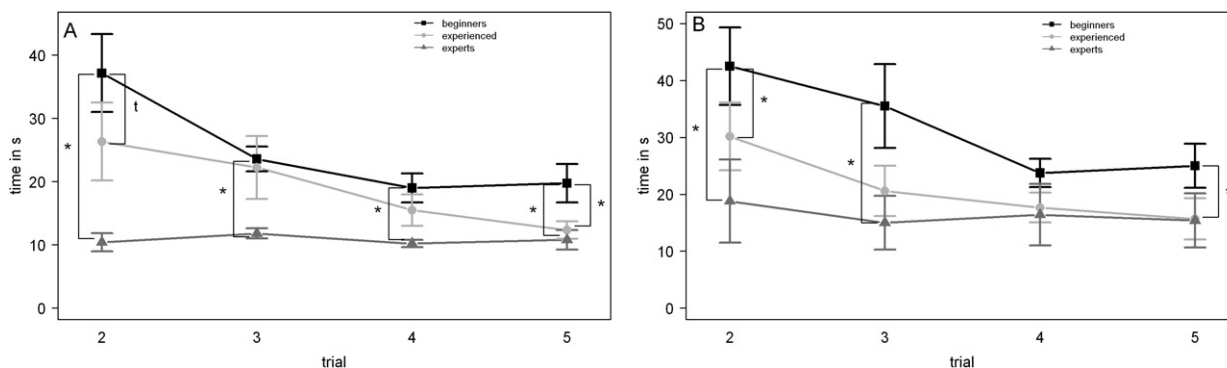


Figure 3 Average time needed to reach the target during intercostal nerve (ICB) (A) and stellate ganglion block (SGB) (B); error bars depict the standard error; the first nerve block is not shown due to assistance by an experienced user. For the ICB of the beginners, post-hoc tests revealed a significant improvement between the second and third ($W = 10, P = 0.023$), second and fourth ($W = 11.2, P = 0.004$), and second and fifth ($W = 0, P = 0.002$) block. The experienced got faster in performing the ICB between the second and fourth ($W = 10, P = 0.041$), second and fifth ($W = 8, P = 0.015$), and third and fifth block ($W = 7, P = 0.021$). For SGB, post-hoc tests showed a significant improvement between the second and fourth ($W = 1, P = 0.003$) and second and fifth ($W = 10, P = 0.023$) block for the beginners and between the second and third ($W = 12, P = 0.034$), second and fourth ($W = 10, P = 0.023$), second and fifth ($W = 9, P = 0.018$), and third and fifth ($W = 9, P = 0.033$) block for the experienced. Significant comparisons between groups are marked with asterisks ($*P < 0.05$).

blood vessels ($H = 1.08, P = 0.582$; beginners: $M = 0.8, SD = 1.06$; experienced: $M = 0.7, SD = 0.99$; experts: $M = 0.2, SD = 0.45$).

Subjective Evaluation of the Curriculum

Altogether, the didactic introduction was evaluated as excellent with $M = 1.3$ ($SD = 0.55$; Table 1), similarly to

the demonstration part with $M = 1.3$ ($SD = 0.53$). The hands-on training was rated between excellent and very good with $M = 1.5$ ($SD = 0.83$). Free comments indicated that some of the less experienced participants wished for more information. The participants rated their own learning success as good ($M = 1.8, SD = 0.79$). The groups did not differ in their evaluation of the curriculum, except when asked how the curriculum is perceived in comparison to

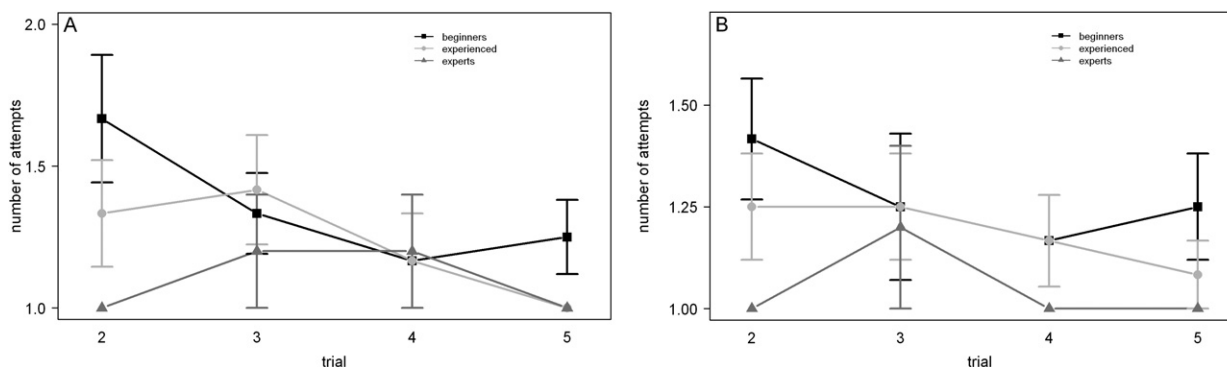


Figure 4 Average number of attempts needed to reach the target during intercostal nerve (ICB) (A) and stellate ganglion block (B); error bars depict the standard error; the first nerve block is not shown due to assistance by an experienced user. Post-hoc tests showed that for the beginners, the number of attempts for the ICB decreased between the second and fourth ($W = 0, P = 0.034$) and, by trend, second and fifth block ($W = 3, P = 0.096$).

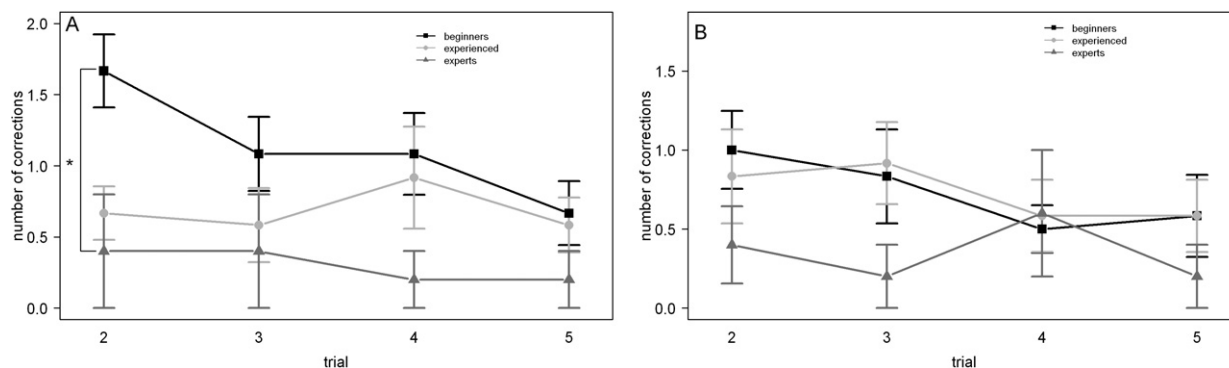


Figure 5 Average number of corrections needed to reach the target during intercostal nerve (ICB) (A) and stellate ganglion block (B); error bars depict the standard error; the first nerve block is not shown due to assistance by an experienced user. During ICB, the beginners made less corrections within the second and third ($W = 0$, $P = 0.038$), second and fifth ($W = 0$, $P = 0.003$), and, by trend, third and fifth block ($W = 3$, $P = 0.096$). Significant comparisons between groups are marked with asterisks ($*P < 0.05$).

the usual training (i.e., watching an experienced operator and then directly carry out the task in a patient). In this case, the experienced group rated $M = 2$ ($SD = 1.2$) and the beginners $M = 1.1$ ($SD = 0.29$; $U = 109.5$, $P = 0.028$; experts: $M = 1.2$, $SD = 0.45$, ns), indicating that beginners preferred the training on phantoms more strongly than the experienced as compared with the usual training. The general benefit of using phantoms for training was rated as excellent ($M = 1.3$, $SD = 0.65$). One “experienced” participant noticed that the phantom’s “skin” felt very soft, unlike a real patient’s tissue. An “expert” participant noted that the ICB phantom was more realistic compared with the SGB model. Finally, another “experienced” participant remarked that especially the ICB phantom was well suited for practice. Further, the SGB phantom was not fully developed and enabled mainly exercising the necessary skills on the phantom but was an insufficient preparation for performance on real patients.

Discussion

The aim of this project was to teach beginners the basics of US-guided SGB and ICB, and to provide them with a safe opportunity for on-site training. In order to guarantee applicability in clinical routine, the amount of time spent was minimized, and easy-to-build phantoms were used. Our results show that participating in the curriculum enabled medical students without experience to increase their puncture speed during both US-guided nerve block procedures, and to reduce the number of attempts and corrections necessary to perform ICB. As expected, the anesthesiologists with some experience showed an intermediate performance level, ranging between the beginners and the experts. They also increased their speed in both procedures. After five completed nerve blocks, the less experienced subjects’ performance nearly reached the performance of the experts. The beginners and the experienced more often than the experts unintentionally punctured the pleura during ICB. The experts’ perfor-

mance was distinguished and did not further improve during the performance testing. Consequently, the curriculum may especially prove beneficial for participants with no or only some experience in US-guided SGB and ICB in acquiring the necessary procedural skills. In contrast to results of the ICB, the number of attempts as well as the number of corrections in SGB did not decrease during the performance test. This may be due to the sound performance in SGB from the beginning, not leaving much room for improvement, since the groups did not show different levels of proficiency. The participants evaluated the curriculum as being very good, rated their own performance as good, and thought that the curriculum could improve their clinical proficiency. The utilization of phantoms for educational training was highly accepted.

The Phantoms

Issues that have to be taken into account concerning the choice of the simulator comprise costs, ethical considerations, image quality, tactile feedback, and service life [13]. Cadavers, for instance, display the actual anatomical conditions, so that a realistic training situation can be provided [8], but anatomical landmarks are somewhat dislocated from their in-vivo position, and accessibility is limited for many medical schools and hospitals. Other options are phantoms assembled with gelatin [14], saline [15], or perishable products, such as meat [9,16] or other foods [13]. Although meat may well imitate muscle tissue, specific anatomical conditions are difficult to simulate, and hygienic concerns have to be considered. Recently, a combined ultrasound and fluoroscopic phantom made of liquid plastic was presented that incorporated fluid-filled vertebral arteries [17]. However, none of the introduced phantoms allowed the visualization of other soft tissue structures, like muscles or specific organs. Finally, industrially produced phantoms are available, but they are expensive and often lack the exact imitation of specific anatomical characteristics. The mixture of guar gum and

borate we used for the phantoms proved advantageous: In contrast to gelatine-based phantoms, the puncture channels closed after removal of the needle, and, when stored in the refrigerator, the phantoms were reusable for about 3 days before the guar gel decomposed, impairing the ultrasound image. The initial development of the phantoms was laborious as gels with varying consistencies imitating different tissues had to be produced. However, the presented phantoms are unique in that they simulate soft tissue structures, like major vessels, muscles, trachea, esophagus, and thyroid (SGB phantom) or accordingly pleura, lung, and muscles (ICB phantom). Overall, the ICB phantom imitated the in-vivo conditions better than the SGB phantom (cf. Figures 1A,B and 2A,B) as noted by two participants. Research shows that closeness to reality of the simulator improves the learning process in simulation-based training (simulation fidelity) [18]. Likely, a realistic imitation of the US anatomy in the phantom leads to better recognition of anatomic structures in the real patient due to the visually detectable similarities between patient and phantom. Thus, by using realistic phantoms, nerve blocks can potentially be performed more efficiently, and risks may be anticipated more easily in real patients.

The Curriculum

Performing US-guided ICB and SGB is rated with an intermediate level of difficulty [2]. Although evidence is scarce [3], studies show that US-guided ICB and SGB yield an equal degree of pain reduction compared with conventional techniques and allow for a reduction of the amount of applied local anesthetic resulting in fewer adverse side effects [5,19]. Despite an increasing demand of US-guided pain procedures, teaching of those techniques has been mostly neglected in clinical practice. In the past, medical education was predominantly accomplished by didactic sessions and by clinical mentorship [20]. However, due to the ongoing technological advancement, physicians constantly need to acquire and train new visual-spatial skills in order to safely apply novel state-of-the-art techniques. Accordingly, several skills are needed to perform US-guided nerve blocks safely [2,21]. Studies show that physicians have to perform 15 nerve blocks until a reasonable quality is reached [22]. To acquire these skills, the US-American (ASRA), European (ESRA), and Asian-Australian societies of regional anesthesia and pain medicine recommend the use of phantoms and to have experienced individuals initially supervise the application of the techniques providing mentoring and support to beginners [2]. Simulation-based curricula have shown to effectively help physicians in mastering the relevant skills faster and better as compared with curricula without implemented simulator-based training [5,6,12]. They mainly address Bloom's psychomotor learning domain, allowing the operator to attain basic levels of competence before patient encounters, to learn to avoid errors, and to treat adverse events [20]. According to the three-stage-model of motor skill acquisition [23], learners have to evolve from the "cognitive" stage, in which they have to understand a task by explanation and demonstration, to the stage of "integra-

tion," in which they comprehend and perform the mechanics through deliberate practice and feedback [24], to finally achieve the "automation" stage, in which they can automatically perform the task fast, efficiently, precisely, and with little cognitive effort. Simulation-based approaches have shown to enhance this process while increasing patients' safety and improving outcomes [20]. Moreover, the self-assuredness of the operator may increase during practicing in a safe environment [10]. Evidence shows that interventions are indeed performed faster and with fewer errors after simulation-based training compared with no prior practicing and that adverse events occur more infrequently [25,26]. Still, simulation-based training is rarely implemented in the clinical practice [7]. The costs can be high, especially when industrially produced phantoms are used. Moreover, the training should be integrated into a comprehensive framework [10,27], which requires financial and staff resources. Time is another limiting factor. Physicians either have to be released from their clinical tasks or participate during their off-duty time, which may lead to organizational and financial concerns.

Only few validated curricula for US-guided techniques exist, although a recommendation of ASRA and ESRA has been published [2,28]. A six-step curriculum has been suggested for regional anesthesia of peripheral nerves [4], including teaching of anatomy and US basics, a hands-on workshop using test persons, a workshop on needle guidance using phantoms, a workshop on cadavers, and supervised performance of the nerve blocks in patients. The curriculum presented in this study largely follows these suggestions but attempted to consider the above-mentioned constraints. Due to financial and organizational issues, the curriculum was tailored to satisfy the requirements of clinical practice, resulting in a low-budget, easily applicable yet comprehensive program, requiring little time and few preconditions. It meets most of the recommended [4,10,21,27,28] and the particularly important criteria, such as feedback option, deliberate practice, and curriculum integration [18].

Limitations

A general disadvantage of phantoms is the fact that anatomical variations are not considered so that the transfer to real patients is limited. Phantoms are not able to mimic in-vivo conditions in every detail. The participants noted that the phantoms' "skin" was different than human skin and that the SGB phantom was not as realistic as the ICB phantom. Although we copied soft tissue structures that are usually absent in most self-assembled phantoms, especially the SGB phantom needs further improvement. Ordinarily, penetrating the fascia of the longus colli muscle is the target of ultrasound-guided SGB. Due to the missing fascia of the longus colli muscle, we had to go back to bone contact indicating successful blockade. Also, we only taught the out-of-plane approach, instead of the in-plane approach. The out-of-plane technique was also used in the pilot study of Kapral [5], first demonstrating ultrasound-guided SGB. We are aware of the fact that the in-line technique has advantages compared with the

offline technique and that it is well described for ultrasound-guided SGB (c.f [19]). Performing the out-of-plane technique in our phantom, however, would have been impossible since a bowl-shaped form was required during the preparation of the phantom to prevent the agar from leaking out of the chamber.

Further, in clinical practice it is important, for example, to detect and count the cervical segmental levels in vivo at the long-axis position, but our SGB phantom only contained anterior partial structures around the C5, C6, and C7 vertebral level. This training can only simulate a part of the complex maneuvers necessary for a blockade in real patients.

Finally, the number of blocks performed in this study was quite small. However, our goal was to introduce a time sufficient curriculum that fits in well in clinical routine. Although the outcome confirms the assumption that this study was not underpowered, future studies should replicate the results with a greater number of blocks.

Future Studies

To validate the benefit of the curriculum for teaching purposes, it would be worthwhile to compare performance of the nerve blocks in a group of subjects that received the training intervention and a group that did not receive it. For future research, it will be necessary to amend the curriculum by repeated supervised practice units on patients and to prove a benefit for patient outcome variables. Long-time effects of the training should be investigated, for example 6 months after the intervention. Further, the phantoms, especially the SGB phantom, should be adapted to better mimic the in-vivo conditions, and to allow teaching of both the in-plane and out-of-plane approach.

Conclusions

The comprehensive curriculum including the training of nerve blocks in realistic US phantoms is useful in the education of physicians and medical students. It can be easily applied and incorporated into teaching programs for nerve block pain procedures in the daily routine of hospitals.

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