Educational and clinical aspects of peripheral nerve blockade
Wegener, Jessica

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Chapter 2

Time to stop ‘learning by doing’ in regional anesthesia

Jessica T. Wegener, Markus F. Stevens, Markus W. Hollmann, Benedikt Preckel, Jens Kessler

Submitted

Summary Statement
The literature on education and learning of ultrasound-guided regional anesthesia (UGRA) is reviewed. Models, phantoms, cadavers and simulators are useful tools educating UGRA, but more research is needed to avoid learning while doing blocks in patients.
Abstract

Background
The American Society of Regional Anesthesia and Pain Medicine (ASRA) and the European Society of Regional Anaesthesia and Pain Therapy (ESRA) Joint Committee has given recommendations on education and learning of ultrasound guided regional anesthesia (UGRA). A survey in the Netherlands revealed that there are no structured curricula for training UGRA for residents or attendants in any teaching hospital. A minority of centers offers some kind of education in UGRA, but the teaching material varies tremendously in content, extent and techniques employed.

Methods
We did a systematic review of the literature on education in UGRA. The results were structured according to the ESRA/ASRA recommendations on the 4 steps of UGRA education.

Results
Although the quality of most studies is moderate to weak, there are quite a few findings that are interesting. Single teaching sessions with electronic tutorials and e-learning modules can increase comprehension of ultrasound technique and sonoanatomy, although the effects are small. Sophisticated medium- to long-term teaching programs using measurable parameters to control learning progress generally displayed better results, pushing the trainees to the asymptotic part of the learning curve. These manual skills can be developed without touching a patient, thereby avoiding ‘learning by doing’.

Conclusions
There is urgent need for further research comparing different educational techniques, for the development of true high-fidelity simulators and testing their efficiency. Education programs should be tailored to the individual needs of a trainee. Furthermore, the effects of improved training programs on patient safety and quality of care have to be investigated.
Chapter 2

Time to stop ‘learning by doing’ in regional anesthesia

Introduction

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**Introduction**

In the recent years, new techniques have been introduced into clinical routine anesthesia practice, including widespread use of ultrasound. This new technique is used during placement of central venous lines with convincing evidence for improved patient safety,¹ placement of arterial and peripheral venous lines, trauma admission to the emergency room, cardiac care as well as in invasive acute and chronic pain treatment. All these indications for ultrasound need special training. Ultrasound guided regional anesthesia (UGRA) is a challenging, complex skill and requires competence, which is far different from standard techniques in anesthesiology. Some data suggest that the use of ultrasound for regional anesthesia contributes to patient safety, although this has not been proven.² Technical developments in UGRA itself, like new linear transducers with a higher frequency range and smaller footprints, portable machines with an improved software package for better target visualization, and needles with a modified surface to change the beam reflection cannot guarantee for improved patient safety. Therefore, the question ‘Can ultrasound increase the safety of regional anesthesia procedures?’ should be rephrased into ‘how can we teach UGRA in order to increase patient safety?’.

There is a growing awareness and general believe that teaching methods like ‘see one, do one, teach one’ and ‘training on the job’ impair patient safety and quality of care, since it may increase the risk of complications and injury.³ Learning by doing without substantial experience from previous lectures, hands-on and simulation training sessions has some other drawbacks like dependence on case mix and capacity, increase of procedure time, a higher risk of unsuccessful blocks, more procedure-related pain and patient discomfort, and misuse of ultrasound equipment resulting in technical damage of the machine or ultrasound transducer. However, present-day anesthesiologists became professionals by ‘see one, do on’ teaching methods. For obvious reasons we have to leave the old ways and discover new learning methods enabling to achieve an expert-derived level of performance in UGRA before starting in clinical practice.
Methods

Literature Search
To ascertain what is known about education and training methods to improve proficiency in UGRA, a literature search was conducted to English written journals in the database PUBMED until January 2013. The following combined medical subject headings were used: [Ultrasonography] AND [Education] OR [Teaching] AND [Anesthesia, Conduction]. After excluding reviews, letters, comments, editorials and unrelated articles 31 abstracts were captured of which 22 original articles contributed to learning of UGRA. Main criterion for the selection was: ‘would the information of the article help to achieve a better quality of education of UGRA?’ Two authors, JTW and MFS checked reference lists of the selected articles independently and found 5 additional articles of interest that were not captured in our search. A flow diagram of the search is shown in Figure1. Quality according to the GRADE guidelines (from the Grading of Recommendations Development and Evaluation working group) and study design of the selected publications varied widely: only 3 randomized controlled trials were found, but many observational studies, some surveys and reports. Selected publications were reviewed and categorized according to didactic components for UGRA.4, 5

Classification of the 27 selected publications in respect to education of UGRA was performed in 6 sections:
1. Understanding device operations
2. Image optimization
3. Image interpretation
4. Visualization of needle insertion and injection
5. Miscellaneous or general issues
6. How much education is necessary

1. Understanding device operations
Only one observational prospective study reported a pre-training quiz of 32 tested components of a portable ultrasound machine, where 10 trainees described 23% components correctly and 18% correctly described function of each component.6 Thereafter, a presentation was shown to demonstrate the dials of settings and functions. Probably, trainees learned what was lacking in their knowledge. Unfortunately, a post-training quiz was not conducted, withholding the results of the presentation. Besides, it remains unclear whether knowledge of physics and artefacts of ultrasound were also tested.
Flow diagram of literature search in PubMed until January 2013

**Search**

1. [Anesthesia, conduction] AND [Ultrasonography]
   - 71 publications

2. Lasts 10 years, English only
   - Exclusion of reviews, editorials, letters, comments, unrelated publications
   - 68 publications

3. Selecting abstracts concerning learning UGRA
   - 31 publications

4. Addition of articles of interest from reference list and cross referencing
   - 22 publications

**Analysis**

- 27 publications

*Figure 1* Flow diagram of literature search in PubMed until January 2013
Although knowledge of the machines used is of uttermost importance, there are no e-learning modules or standardized test to verify adequate skill to handle an ultrasound machine. This is surprising, since adequate introduction into any medical device is mandatory in many countries.

2. Image optimization
Correct device settings and efficient transducer movements are fundamental to image optimization. It was well shown that the unintentional probe movement is one of the most frequently (26.9%) committed errors. Automated movement analysis systems have shown that during the increase of dexterity the frequency and amplitude of movements and thus time required are reduced. Chin et al. objectively investigated hand movements during scanning and needling phase of residents, fellows in UGRA and experienced anesthesiologists (consultants). Time and amplitude of movements were significantly shorter in the consultant group compared to residents, while number of movements per minute was similar. In fellows, the time required to perform a supraclavicular block at the end of their fellowship was significant reduced compared to the start of the program. The validated automated movement analysis system used in this study seems an ideal tool to judge on the value of education techniques and paradigms. Thus, validated automated movement analysis systems should be used as auto-feedback for the trainees and to monitor the progress in motor learning for image optimization next to guidance of an experienced mentor.

3. Image interpretation
For identifying target structures and avoiding significant damage, knowledge of sono-anatomy is of great importance during performance of UGRA. Most trainees need to refresh anatomy and have to be introduced into sono-anatomy. In a randomized controlled study in UGRA novices (n=35) Wegener et al. evaluated the value of an on-site electronic tutorial. The number of correct identification of 27 anatomical structures related to the brachial plexus improved significantly from 50% to 62% when using an on-site tutorial on the ultrasound machine. Four weeks of training in UGRA significantly improved the number of correct identification of anatomical structures (mean 9.9 vs. 14.1) in an observational study. During scans for ultrasound guided pediatric ilioinguinal blocks, 6 novices reliably identified bony landmarks after 7 scans while reliable identification of the ilioinguinal and iliohypogastric nerves occurred after 18 scans. Another option for beginners to identify the correct nerves non-invasively might be parallel use
of ultrasound and percutaneous nerve stimulation. Unfortunately, the correlation between localization by percutaneous nerve stimulation and the ultrasound picture is rather poor.\textsuperscript{11}

In conclusion, electronic tutorials can improve understanding of sono-anatomy to some degree, but especially difficult anatomical structures require feedback by an experienced teacher.

4. Visualization of needle insertion and injection

Niazi et al. showed in a randomized controlled trial that an hour simulation training on a low fidelity simulation model for needling and proper hand eye coordination, in addition to a conventional training, success rates of residents improved significantly from 51.3\% to 64\%.\textsuperscript{12} Prolonging simulation training from one to two hours improved accuracy and shortened time to reach a target in a low fidelity simulation experiment.\textsuperscript{13} Whether providing more variability by simulation training on high fidelity models could further improve success rate is unknown. However, Tsui described both the usefulness and the obstacles of human cadavers for training UGRA: advantages of learning the sonographic anatomy and becoming aware of the vicinity of vital structures, but on the other hand the rigidity resulting in poor positioning and imaging, the lack of pulsating arteries as internal landmarks, not enabling the confirmation of Doppler and the inability of using nerve stimulation.\textsuperscript{14}

The number of supervised attempts that are needed for competence in ultrasound needle visualization in a cadaver model was investigated by Barrington et al.\textsuperscript{15} Fifteen trainees performed 30 simulated sciatic nerve blocks in a bovine model, which were supervised and videotaped. After each procedure the supervisor provided feedback in response to ten predefined quality compromising behaviors. Videotapes of each procedure were analyzed by only one blinded observer assessing needle visualization and transducer steadiness on the basis of a predefined scoring system. Learning curves were constructed for each trainee and categorized into proficient, not proficient and undetermined. A wide variability in individual learning curves was found and an estimation of 28 supervised attempts was calculated for a success rate of 90\%. The three most common quality compromising behaviors that provided feedback were poor transducer handling, malpositioning of the target nerve on screen and advancement of the needle while not visualized. Similarly, De Oliveira constructed mathematical learning models to extract learning curves for basic skills in UGRA.\textsuperscript{16} Thirty trainees performed 25 attempts compromising one experiment for needle visualization and a second experiment for injecting saline...
around a target structure without any feedback. Experiments were recorded on videotapes and reviewed independently by two blinded observers, rating the performances according to predefined image quality scores. Any discrepancies were re-evaluated by the observers together. Only 30% of the trainees attained proficiency advancing the needle in-plane and only 11% of the trainees managed to deposit saline around a target. It was calculated that the trainees would require 37 attempts for a visible advancement of a needle in-plane and 109 attempts for learning adequate deposition of the local anesthetic. Noteworthy, training experiments were performed without any feedback, which is called ‘discovery learning’ or ‘learning by doing’. This learning method is less efficient at all, because it consumes much more time for practicing and needs much more repetition. Feedback on completion of a task is one of the essences of supervising and stimulates proficiency of trainees. Previously, Sites et al. evaluated learning curves in 10 inexperienced residents, each performing 6 simulations of an ultrasound guided block. The greatest improvements were made after the first and second simulation. The accuracy score increased by 36% and 59%, respectively, compared to the first simulation. Furthermore the time required was reduced in the second and third simulation by 38% and 48%, respectively, also compared to the first. The most common mistake was advancement of the needle without visualization. The same group characterized the learning behavior of 6 residents performing 520 nerve blocks. All blocks were videotaped and reviewed on quantitative and qualitative behaviors by two independent experts. 398 errors were found, divided in 7 quality-compromising behaviors. Again, most common quality compromising behavior was needle advancements without visualization followed by unintentional transducer movements. In this study Sites found some new elements of procedural competence like recognition of maldistribution. In contrast, McCartney et al. demonstrated a very high accuracy of recognizing spread of local anesthetics in trainees. Similarly, Cheung et al. observed mistakes of 26 trainees using a high-fidelity simulator: maintaining visualization of the needle, aligning the needle with the transducer and angling the needle were the most common mistakes. All studies evaluating learning curves in UGRA demonstrated a large interindividual variability. Probably, individual baseline skills of complex and fine motor control and visuospatial awareness determine the progress of proficiency in UGRA. Visuospatial awareness is the mental process that involves visual and spatial awareness. E.g. visuospatial awareness is needed in UGRA to work from a visual 2-dimensional ultrasound image to 3-dimensional needle advancement in direction of a target. How can we identify
trainees with low capacity and even more important: can we improve baseline skills for low capacity trainees?

Smith et al. evaluated predictors of ultrasound-guided procedural performance in 40 trainees of UGRA.21 They measured motor and visuospatial skills by Block Design Test, which is a validated subtest of the Wechsler Adult Intelligence scale III. This test was strongly correlated with the performance success of a simulated ultrasound-guided nerve block. Furthermore, subjects who commonly practiced dexterous activity, like piano playing or video games, performed significantly faster in ultrasound skill assessment. In contrast, psychomotor performance in a couple of validated tests did not correlate with performance in ultrasound-guided skill assessment. Thus, it will be interesting to investigate whether specific training of visuospatial skills can improve performance of UGRA. A Virtual Reality (VR) based environment has been described that will adapt to the skill level of the trainee and assess their progress providing the outcome to trainers. In this way, measuring quantity and quality of errors, providing prompt feedback and individualized training could be realized. However, such simulators have to be validated.22 There have been proposals what an ideal high-fidelity simulator should be capable of.23 Thus, the development of high-fidelity simulators with automated prompt feedback will be an important direction of future research. Until then, training in UGRA should be done in cadavers and phantoms under the guidance of an experience teacher.

5. Miscellaneous or general issues

In order to assess technical skills of UGRA Cheung et al. proposed an assessment tool, containing a list of 22 items from which each item should be rated as not, poorly or well performed.24 The list starts with positioning of the patient and ends at recognition of correct spread of the local anesthetic. In addition, for non-technical skills of UGRA a Global Rating Scale of 9 categories was developed applying a 5-point Likert scale score. However, this approach has neither been evaluated nor validated.

For beginners in UGRA outside a teaching hospital, a large gap between following courses with hands-on workshops and the start of UGRA in daily practice has to be overcome. In a small survey the level of comfort of trainees (n=12) and their intention to perform UGRA in their daily clinical practice were tremendously increased after a web-based simulator training.25 However, the motivation was halved again after one further month. Sufficient training opportunities afterwards was found to be one of the most important determinants of getting experienced.
in UGRA followed by the presence of high-quality supervisors.\textsuperscript{26} Training should be repeated on a regular base when UGRA is not performed frequently. A very high initial success rate of 97.3\% was found when 22 trainees performed 222 supervised ultrasound guided and nerve stimulated interscalene blocks during a 4-week block rotation. A sound training program proceeded, but its impact on the success rate was not studied and an objective assessment of proficiency was lacking.\textsuperscript{9}

Moore et al. reported the improvement in UGRA-associated skills and proficiency using a dual integrated teaching program with simulators and real time feedback in 9 pediatric anesthesia fellows.\textsuperscript{27} Using a validated simulation and real feedback model for the assessment, technical and cognitive skills of UGRA increased from 56.7\% and 52.5\% in baseline to 78.9\% and 79.2\% after one year respectively. Whether skills would have been less without or would have been improved even more with a more intensive teaching program was not studied. Number of cases in daily practice per trainee was not mentioned and caseloads were not included in the assessment. Recently, Rosenberg et al. described 3 well developed high fidelity simulation models with pulsating arteries for most common blocks: upper extremity, femoral and sciatic popliteal.\textsuperscript{28} Until now its value for training is unknown, while the costs of these models will be high. Also Smith et al. described a magnificent learner-centered training model that requires self directed knowledge and skill development, based on what is learned rather than on what is taught.\textsuperscript{29} Internet-based e-learning modules and several internet pages like the recently established ESRA Academy among others offer a range of opportunities to expand the knowledge on sono-anatomy, provide manuals of ultrasound machines and show block performance. However, the efficiency and efficacy of all these tools on successful block rate and procedure-related complications have not been evaluated until today.

In conclusion, the attention on all levels of learning should focus more on what is learned than on what is taught.

6. How much education is necessary?

Determining caseloads requirement is of great importance for training of residents and inexperienced anesthesiologists. Traditionally, caseloads have been determined for peripheral nerve block to establish a specified level of proficiency in the training curriculum of an anesthesiologist. Thus, patients were exposed to doctors suboptimal in proficiency and safety of the procedure. Fortunately, most studies investigating dexterity and learning curves in UGRA
are done in cadavers or phantoms. However, not all simulation training could improve performance immediately. Furthermore, the slopes of the learning curves in sono-anatomy recognition seem to vary tremendously between different blocks. Performance of 18 scans was sufficient for a reliable identification of the ilioinguinal and iliohypogastric nerve, whereas none of 18 anesthesiologists achieved competence in the sono-anatomy of the lumbar spine after 20 supervised scanning trials. Regarding performance of blocks Luyet et al. demonstrated that novices in UGRA reached the plateau of the learning curve after just 13 blocks, whereas Sultan et al. observed that anesthesiologists required more than 100 axillary plexus blocks for having a significantly better technique than those with an experience of 50-80 blocks. To achieve competence in performing a simulated sciatic nerve block novices required 28 blocks. This tremendous variation in attempts required to achieve competence is most likely due to the different variables taken as measurement of ultrasound skills. While Luyet et al. defined a surgical block as success, Sultan et al. evaluated the technique on a 63-point task-specific scale. Thus, for UGRA there are no generally predefined required ‘case load’ numbers for a novice to gain sufficient experience to safely and efficiently perform an ultrasound guided block. Therefore, it will be of imminent importance that skills in UGRA will be identified, which are testable, clinically relevant and valid. These skills have to be acquired before trainees perform their first block in patients. However, in a survey of ASRA members practicing UGRA more than 80% had no experience with cadaver or animal training and the greatest amount of time in training of UGRA was allocated to ‘self taught’. In conclusion, the attention should switch from caseload requirement for learning a technique to finding testable indicators of sufficient skills on every level of learning.

What is recommended?

The American Society of Regional Anesthesia and Pain Medicine (ASRA) and the European Society of Regional Anaesthesia and Pain Therapy (ESRA) Joint Committee published recommendations for education and training in UGRA in 2009 and 2010 and recently completed these recommendations for ultrasound-guided procedures in pain therapy. The committees summarized the 10 common tasks used when performing an ultrasound-guided nerve block (see Table 1) and described the core competencies and skill sets associated with UGRA. They also showed both a training practice pathway for postgraduate anesthesiologists and a residency-based training pathway to present adequate
ideas for each training level. Furthermore, they announced the review on a periodic basis and the publication of updates and modifications to these recommendations when appropriate.

**Recommendations of the ASRA/ESRA Joint Committee in the Netherlands**

We also evaluated the implementation of the recommendations of the ASRA/ESRA Joint Committee by telephone interviews with all educational institutions for Anesthesiology in the Netherlands. To date, the recommendations have not been adopted or integrated in any curriculum of the residency program. In addition, preliminary attempts for an Introduction program of UGRA in the curriculum are lacking in the Netherlands up to now, while regional anesthesia is a mandatory part of the curriculum. Three of the eight Dutch training programs offer an institutional education in UGRA for residents, differing in time, frequency and content. These programs largely depend on the commitment of a few interested experts and mainly on the interest of the individual resident.

**Training ultrasound in other medical specialties and training models**

A literature search was conducted to training models for ultrasound in other medical specialties in order to determine what kind of models from other specialties we can adopt for UGRA. Results of this search are shown in table 2. Surgeons described significantly improved skill performance after simulation and proficiency based surgical education of residents.44 The use of simulation models to assist with the teaching and learning of laparoscopic operation skills offers advantages of learning in a safe environment that promotes problem solving, questioning and transformational learning. Objective assessments of performances is an important instrument for allowing evaluation of level and progress of learning. Translating these technical possibilities of stimulation models into the field of UGRA would be an advantage for all learners.
List of 10 tasks that are helpful in performing an ultrasound-guided nerve block

1. Visualize key landmark structures including blood vessels muscles, fascia, and bone.
2. Identify the nerves or plexus on short-axis imaging.
3. Confirm normal anatomy and recognize anatomic variation(s).
4. Plan for a needle approach that avoids unnecessary tissue trauma.
5. Maintain an aseptic technique with respect to the ultrasound equipment.
6. Follow the needle under real-time visualization as it advances toward the target.
7. Consider a secondary confirmation technique, such as nerve stimulation.
8. When the needle tip is presumed to be in the correct position, inject a small volume of a test solution. If solution is not visualized during this test injection, presume that the needle tip is intravascular or out of the imaging plane.
9. Make necessary needle adjustments if an undesired pattern of local anesthetic spread is visualized. The visualization of local anesthetic should occur through the entirety of the injection to avoid an intravascular injection.
10. Maintain traditional safety guidelines including the presence of resuscitation equipment, frequent aspiration, intravascular test dosing, standard monitoring, patient response, and assessment of injection characteristics.

Table 1
List of ten common tasks used for performing UGRA, formulated by jointed committees of ASRA
<table>
<thead>
<tr>
<th>Training model</th>
<th>Purposes</th>
<th>Results</th>
<th>Speciality (author)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer based simulation with 3-dimensional heart model</td>
<td>Diagnosing abnormal fetus</td>
<td>Spatial orientation skills</td>
<td>Obstetrics (Lee)³⁵</td>
</tr>
<tr>
<td>Simple Gelatin mold for needle insertion, track and tip visualization</td>
<td>Ultrasound guided amniocentesis</td>
<td>Reducing threats to patient safety and operator confidence</td>
<td>Obstetrics (Smith) ³⁶</td>
</tr>
<tr>
<td>VR-patient model *</td>
<td>Ultrasound examination in pelvic pathology</td>
<td>Probe movement and visualization of pelvic pathology</td>
<td>Gynaecology (Heer)³⁷</td>
</tr>
<tr>
<td>Plastic spine in water and cadaver specimen model</td>
<td>Diagnosing spinal stenosis during spine surgery</td>
<td>Reliable detection of spinal stenosis</td>
<td>Neurosurgery (Fritz)³⁸</td>
</tr>
<tr>
<td>Living animal model</td>
<td>Laparoscopic ultrasonography in detecting liver colorectal metastases.</td>
<td>High accuracy rate of detecting</td>
<td>Surgery (Restrepo)³⁹</td>
</tr>
<tr>
<td>Life like model: Plexiglas tube and porcine colon with plastic bags</td>
<td>Endorectal ultrasonography for diagnosing and treating anorectal pathology</td>
<td>Acquired technical skills for diagnosing and interventional procedures</td>
<td>Enteral Endoscopy (Bussen)⁴⁰</td>
</tr>
<tr>
<td>Synthetic arm skin filled with a mix of gelatin and fiber.</td>
<td>Ultrasound guided vein cannulation</td>
<td>Faster vascular access</td>
<td>Emergency Medicine (Blaivas) ⁴¹</td>
</tr>
<tr>
<td>Living animal: anesthetized pigs with intra thoracic or intraabdominal fluid</td>
<td>Diagnosing intraabdominal and intrathoracic bleeding in trauma patients</td>
<td>Decrease of error rate from 17 to 5% after tenth examination</td>
<td>Traumatology (Abu-Zidan)⁴²</td>
</tr>
</tbody>
</table>

Table 2  An overview of simulation training models outside the field of UGRA, stating the learning objectives and outcome. * VR: virtual reality.
Conclusion

Learning by doing impairs patient safety and quality of care. Understanding of the ultrasound device should be standardized and testable, which might easily be included in an e-learning module. Correct device operation will be the first requirement of image optimization. Handling of the probe can be trained by giving feedback on the frequency and amplitude of movements. Possibly, such automated dexterity feedback may guide training more effectively than just looking for an optimal picture. Also image interpretation can be enhanced by electronic tutorials for novices. However, for in-depths learning especially of difficult or deep anatomical structures an experienced trainer will be indispensable. The most common mistake of needle insertion is advancement of the needle without visualization. Furthermore, correct deposition of fluid around a target structure is a very difficult for a beginner. These tasks can easily be learned in cadaver or phantom, but direct feedback is required to accomplish fast learning. Since these are only visuospatial and motor task, it might be possible implement automatic feedback learning in a high-fidelity simulator. For the time being, experienced teachers giving frequent feedback are inevitable in guiding needle insertion and local anesthetic deposition. The evaluation of skills on every level of learning and the curriculum should not be standardized for all trainees, but individualized to each trainee, because inter-individual learning curves can vary tremendously. Similarly, because of these varying slopes of learning curves, no fixed numbers can be given to acquire proficiency in a certain technique. Thus accomplishment of a technique must be evaluated by skill testing and by number of blocks performed. A lot of UGRA learning can already be done and evaluated with e-learning, examining models, training visuospatial and motor skills in cadavers, phantoms and simulators. However, a lot of research is needed validating these training techniques and adequately defining and testing UGRA skills.
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