Training in and assessment of the procedural skills required to perform peripheral nerve blockade

By

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at

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All Research was conducted in Department of Anaesthesia, Intensive Care and Pain Medicine.

Cork University Hospital and University College Cork

Submitted in September 2013

Supervisors:

Professor George Shorten

Dr Gabriella Iohom

Declaration

This thesis is submitted to the University College Cork, for examination for the degree of Doctor of Philosophy. It has not been submitted as an exercise for a degree at this or any other University and it is entirely my own work. I have carried out all the practical work except where duly acknowledged. I agree to deposit this thesis in the University's open access institutional repository or allow the Library to do so on my behalf, subject to Irish Copyright Legislation and University College Cork Library conditions of use and acknowledgement.

Syed Farjad Sultan

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Publications arising from thesis

1. A clinical assessment tool for ultrasound-guided axillary brachial plexus block.

   Sultan SF, Iohom G, Saunders J, Shorten G.

   Acta Anaesthesiol Scand. 2012 May; 56 (5): 616-23. Epub 2012 Mar 7.

2. Effect of feedback content on novices' learning ultrasound guided interventional procedures.

   Sultan SF, Iohom G, Shorten G

   Minerva Anesthesiol. 2013 Jun 10

3. Simulators for training in ultrasound guided procedures.

   Farjad Sultan S, Shorten G, Iohom G

   Med Ultrason 2013 Jun; 15(2): 125-31

4. A Novel Phantom for Teaching and Learning Ultrasound-guided Needle Manipulation

   Sultan SF, Iohom G, Shorten G

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Abstract publications and presentations

1. A Novel Phantom for Teaching and Learning Ultrasound-guided Needle Manipulation

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2. Validation of a clinical assessment tool for ultrasound guided axillary brachial plexus block.

   Sultan SF, Iohom G, Shorten G.

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   Poster presented in The European Anaesthesiology Congress – Euroanaesthesia 2011.

   Poster presented in Irish Congress of Anaesthesia 2011.

3. Effect of feedback on novices learning in-plane technique for ultrasound guided interventional procedures.

   Sultan SF, McCarthy D, O'Donnell B, Iohom G, Shorten G

   Eur J Anaesthesiol. 2011 Jun; Volume 28; Supplement 48; 15AP2-5: p 213-214.

   Poster presented in The European Anaesthesiology Congress – Euroanaesthesia 2011.

   Oral presentation in Irish Society of Regional Anaesthesia 2011

4. A comparison of Immediate learner-led versus terminal feedback on skill acquisition for ultrasound guided needle manipulation in a simulated setting.

   Sultan SF, Iohom G, Shorten G.

   Oral presented in 30th Annual ESRA Congress 2011 – Dresden, Germany.

   Oral presentation in Irish Congress of Anaesthesia 2011 – 1st Prize.

5. Effect of an intense training programme for identification of brachial plexus in the axilla using ultrasound guidance by novices.

   Sultan SF, Loughnane F, Iohom G, Shorten G.

   Poster presentation in Irish Congress of Anaesthesia – 2012.

   Poster presentation 31st Annual ESRA Congress 2012 – Bordeux, France

Table of Content

1 The proposal and amendments

Syed Farjad Sultan

PAC Number: 10221112

Title: Learning and assessment of procedural skills in regional anaesthesia/ peripheral nerve blockade.

Location: All work will be carried out in Cork University Hospital and University College Cork Campus.

Supervisors:

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1.1 Overall Objective: To characterize the learning patterns and enhance assessment of the procedural skills required to perform peripheral nerve blockade.

1.2 Projects:

1.2.1 Validation of a clinical assessment tool for ultrasound guided axillary brachial plexus block.

1.2.2 Effect of feedback on novices learning in-plane technique for ultrasound guided interventional procedures.

1.2.3 Immediate versus delayed feedback on acquisition of skill using ultrasound guided needle manipulation in a simulated setting.

1.2.1 Validation of a clinical assessment tool for ultrasound guided axillary brachial plexus block

Axillary Brachial Plexus Block (ABPB) is the most commonly performed form of peripheral nerve blockade.[1] Anatomically, the brachial plexus is easily accessible in the axilla and the different nerves are identifiable in spite of the anatomical vaiations.[2,3] Ultrasound guidance for nerve localization has been shown to improve success rate, shorten procedure and onset time and extend block duration.[5] The use of ultrasound guidance for peripheral nerve blockade requires high-level ultrasonographic equipment and intensive formal training.[2] Optimal training in medical procedural skills, such as peripheral nerve blockade, requires valid and reliable forms of assessment. Competency in anaesthesia traditionally has been determined subjectively in practice.[6] Objective assessment tools may improve these evaluations.

Construct Validity is defined as "a set of procedures for evaluating a testing instrument based on the degree to which the items identify the quality, ability, or trait it was designed to measure". As more traits or performance qualities are identified, construct validity must be updated[4].

The purpose of this study is to clinically validate a Clinical Assessment Tool (CAT) for UgABPB for construct validity and reliability.

Objectives

i) To validate a Clinical Assessment Tool (CAT) for Ultrasound Guided Axillary Brachial Plexus Block (UgABPB) in a clinical setting for construct validity, ii) to determine the reliability of the CAT in a clinical setting.

Methodology:

This will be a prospective, observational study. After regional institutional ethical committee approval, informed consent will be obtained from 15 anaesthetists, divided into 3 groups, expert, intermediate and novice according to the experience of the individual. Each participant will perform two UgABPB, which will be video recorded and assessed by two blinded assessors, with expertise in ultrasound guided regional anaesthesia. All participants will be supervised and will be provided with a trained assistant. 30 patients with upper arm plastic or orthopaedic injury requiring axillary brachial plexus block will be recruited. Standard exclusion criteria will be used. The demographics collected will include age, gender, hand dominance and visual acuity. Other end points will include need for sedation, timing and total dose of sedative agent administered. The need to convert to general anaesthesia, the onset of the block, using sensory and motor testing every 5 minutes till a maximum of 30 minutes. Patient satisfaction will be scored in recovery, before the patient is discharged to ward on a 5 point Leikert scale.

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1.2.2 Effect of feedback on novices learning in-plane technique for ultrasound guided interventional procedures

One of the most important variables in motor-learning process is the feedback provided to the learner attempting to acquire a new motor skill.[1] Feedback in the context of motor learning research usually involves information about the outcome (termed “Knowledge of Result” KR) or the quality of the movement (termed “knowledge of performance” KP) [2,3]. KR is information provided to individuals about the endpoint of their motor movement, such as the time it took them to perform a particular task. KR does not provide any information as to how the movement itself was carried out. KP refers to information pertaining to the movement patterns that the individual performs. It is the method by which an instructor may point out various mistakes in the steps an individual takes to perform a particular task rather than critiquing the endpoint of the movement. Studies have addressed issues such as the effect of feedback frequency, timing, accuracy or error estimation. These research have provided important insight into the role of augmented feedback in learning.[4, 5] Recent studies have also examined the role of feedback in the performance and learning of surgical skills, such as suturing or knot-tying.[3, 6]

The key requirement for successful regional anaesthesia is to ensure optimal distribution of local anaesthetics around nerve structures. This is most effectively achieved under sonographic visualization[7]. Ultrasonographic guidance produces a higher rate of block success, shorter procedure times, faster onset times, longer block duration and appears to reduce the risk of inadvertent vascular puncture during block performance.[9]

Ultrasound imaging requires the acquisition of an entirely new set of skills regarding device operation and cross-sectional anatomy, which will likely challenge the novice[8]. The most commonly performed error by the novice appears to be advancement of the needle when the tip is not visualized[8].

Information is scarce regarding the details of the learning process and skill development required to conduct safe and effective ultrasound-guided regional anesthesia[8, 10].

Objective:

Our goal is to evaluate the effect of two levels of feedback on novices learning in-plane technique in ultrasound guidance using a gelatin based phantom model[11], to check for retention of skills and to identify factors and behaviors that could help structure ultrasound guided intervention training programmes.

Methodology:

This will be a prospective, randomized, comparative, interventional study. With institutional ethical approval, written informed consent will be obtained from 30 medical college students (3rd, 4th and final year) who have performed no ultrasound-guided procedures. All participants will receive a didactic tutorial on ultrasound, the ultrasound machine and the various components of the machine (i.e. on/off, probe holding, probe orientation, gain, depth, Doppler and image storage). The tutorial will be in the form of a self-timed presentation/video. This time period will be deemed as Teaching Phase.

The participants will be randomized into three groups A, B and C

Group A: no feedback

Group B: will be given feedback in the form of KR at the end of each session in the form of imaging time, needling time, performance time, number of needle passes.

Group C: will be given feedback in the form of KR as described above and KP in the form of advice for the mistakes made, at the end of each series of tasks.

The participants will be asked to perform a series of tasks (six in total) ten times, on a gelatin based phantom model. This will be deemed as the learning phase.

After a time interval of at least 24 hours the participant will perform the same series of tasks, on a phantom model, two times and be videotaped as before. None of the participants will receive any feedback. This time period will be deemed as Assessment Phase.

Two independent anaesthetists, who will be blinded to the identity, experience and group allocation of the participant will evaluate the videotapes. Error count will be the outcome measures.

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1.2.3 Immediate verses delayed feedback on acquisition of skill using ultrasound guided needle manipulation in a simulated setting.

Feedback is a cornerstone of effective teaching and is considered one of the single most important variables, aside from practice itself, for motor learning[1]. In a review of simulation-based medical education, feedback was identified as the most important feature for effective learning in a simulated setting[2]. Feedback, however, must be delivered in an appropriate manner to maximize learning[3]. Feedback refers to specific information people receive about their performance that is intended to improve future performance.[1, 4] When feedback is provided during the performance of a skill it is referred to as immediate or concurrent feedback, and when provided on completion of a skill it is referred to as terminal, delayed or summary feedback[5]. The timing of the feedback has been shown to influence motor learning for discrete tasks such as suturing.[5] The use of delayed feedback is often limited in the clinical setting out of concern for patient safety, during simulation based training errors can be allowed to progress so trainees learn from their mistakes[3]. Schmidt and Bjork have showed that practice performance improves equally with concurrent or summary feedback, but summary feedback results in better learning when evaluated after a rest period with no feedback.[6]

Objective:

The objective is to determine the effect if any on timing of feedback on learning of needle insertion using ultrasound guidance by novices in a simulated environment.

Methodology:

This will be a prospective, randomized, interventional study. With institutional Ethical approval and having obtained written informed consent from each, 20 medical college students (3^{rd}, 4^{th} and final year) with no experience in ultrasound-guided procedures will be recruited. Each participant will receive a didactic tutorial in the form of a self-timed presentation/video on the principles of ultrasound, the ultrasound machine and outline of the procedure/s that the participants need to perform. Using random number tables participants will be randomly allocated to one of two groups.

Group I: Immediate Feedback

Group D: Delayed Feedback

The immediate feedback group will receive augmented visual feedback on demand. The participants will control the timing, content and frequency of feedback themselves by requesting it or asking specific questions. The delayed feedback group will receive feedback at the end of each set of tasks.

The participants will be asked to perform a series of tasks (five in total) on five successive occasions on a gelatin based phantom model.

The same observer will provide all feedback. The wording of the feedback to both groups will be standardized. Reductions in time to perform and error count will the outcome measure.

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Mr. Syed Farjad Sultan,
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I am pleased to inform you that your recent application has been approved as follows:

PhD(College of Medicine & Health) in Anaesthesia & Intensive Care Medicine
3 years full time from October, 2010
Supervisor(s): Professor George Shorten/Dr. Gabriella Iohom
Nominated By: Professor H.P. Redmond/Professor T. Ryan
Thesis Title/Research Area: Learning and Assessment of Medical Procedural Skills

You will be required to register and pay fees for a minimum of 3 years full-time in order to complete your registration requirements. The three years are as follows:

Year 1 October, 2010- September, 2011
Year 2 October, 2011- September, 2012
Year 3 October, 2012- September, 2013

Information advising you on registration and fees is attached.

All PhD students are strongly advised to consult the Guidelines for a Code of Practice for PhD supervision. Copies of this document can be downloaded at http://www.ucc.ie/en/phd/

While the principal purpose of this letter is to confirm approval of your application, the information attached hereto should be noted for the subsequent processing of your candidature.

I do hope you will find this course both rewarding and enjoyable.

Mise le meas,

Mary Murphy

Mary Murphy,
Graduate Studies.

C.c. Supervisor(s)

1.3 Additional work carried out

1.3.1 Simulators available for ultrasound guided procedures - review of literature

The four major categories of skill sets associated with proficiency in ultrasound guided regional anaesthesia are 1) under- standing device operations, 2) image optimization, 3) image interpretation and 4) visualization of needle insertion and injection of the local anaesthetic solution. Of these, visualization of needle insertion and injection of local anaesthetic solution can be practiced using simulators and phantoms. This survey of existing simulators summarizes advantages and disadvantages of each. Current deficits pertain to the validation process.

1.3.2 A novel phantom for teaching and learning ultrasound-guided needle manipulation

It is recommended that training in ultrasound-guided regional anesthesia should address four skill sets (1) understanding ultrasound image generation and device operation, (2) image optimization, (3) image interpretation and (4) needle insertion and injection[1]. These skills can be acquired through attending peripheral nerve block courses, practicing ultrasound-scanning techniques and learning sonoanatomy by imaging one self and colleagues, and practicing needle manipulation using simulators and phantoms[1]. Sites et al have identified errors characteristic of novice learning of ultrasound-guided peripheral nerve blockade; the most common of these is "advancement of needle when the tip was not visualized"[2].

Simulation is an integral part of training, assessment and research in aviation, nuclear power and the military[3] and is likely to become a mandatory component of training of health professionals[4]. Simulation has a key role to play in enabling development of medical skills from novice to expert[4]. The use of simulation models has been shown to improve skills and success with ultrasound-guided procedures[5]. A phantom may be described as any media other than live human tissue that can be used for research or training. Phantoms provide a (generally) simple tool which one can use to aid learning of the skills of ultrasound-guided needle placement, before clinical use, with the aim of decreasing the incidence of complications[6].

In this article, we describe a gelatine-based phantom that can be used to identify most of the common “novice errors” and to facilitate learning of the relevant skills. This phantom can be constructed from low cost, readily available items, is re-usable and can be modified to present a learner with greater degrees of difficulty as he/she progresses in training with no additional cost.

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1.3.3 Effect of an intense training programme for identification of brachial plexus in the axilla using ultrasound guidance by novices

The use of ultrasound has dramatically increased over the last 5 years. This is evidenced by peer-reviewed articles and educational events dedicated to techniques of ultrasound-guided regional anaesthesia [1,2,3] Ultrasound is used for anatomic evaluations and to facilitate the performance of both neuraxial and peripheral nerve block. According to the joint committee of the American Society of Regional Anaesthesia (ASRA) and European Society of Regional anaesthesia and pain medicine (ESRA) (Joint Committee) recommendations for education and training in ultrasound-guided regional anaesthesia of the listed ten helpful tasks for performance of an ultrasound guided nerve block the top three are: 1 - visualization of key landmark structures including blood vessels, muscle, fascia and bone. 2 - Identification of nerves or plexus on short axis view. 3 - Confirm normal anatomy and recognize anatomical variation.[4] To attain proficiency in ultrasound guided regional anaesthesia the joint committee has further defined the various skill set required into four major categories: 1 – Understanding device operation, 2 – Image optimization, 3- Image interpretation and 4 – Visualization of needle insertion and injection of local anaesthetic solution. The image optimization (non-device related) is to learn the importance of transducer pressure, alignment, rotation and tilt (PART maneuver). The image interpretation is further divided into identification of the nerves, muscle and fascia, to distinguish between artery and veins, to identify bone and pleura, to identify common acoustic artifacts and to identify common anatomic artifacts and variations. The practice pathway recommendation for image optimization and image interpretation is to practice ultrasound-scanning techniques on one-self and colleagues.[4]

Axillary brachial plexus block (ABPB) is one of the most commonly used peripheral nerve blocks for peripheral upper limb surgery[5]. The topographic variation of the four nerves in the axilla is numerous, the most frequent arrangement seen in less than two-third of the patients[6]. The number of attempts necessary to attain proficiency differs from procedure to procedure. The present training programmes extend over a period of weeks to months and are dependant on availability of patients, trainer and trainees to attain the experience and proficiency level. Our goal is to assess the effect of an intensive training program on acquisition, retention and attrition of a procedure.

Objective

i) To assess the effect of an intense training program for skill acquisition, retention and attrition in identification of brachial plexus in the axilla using ultrasound guidance by novices. Secondary objectives are to assess, if any, the years of experience in anaesthesia to skill acquisition, retention and attrition.

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2 Introduction

Medical training is moving towards competency based training programs[1, 2] In order for a training program to be effective, it is important to understand what needs to be taught, how adults learn and the factors which influence learning.[3]

Before training begins, the learning outcomes require clear definition; any form of assessment applied should include measurement of these outcomes. Ideally a valid and reliable assessment tool should be applied for each specific procedure.

2.1 Training – current practice

Currently training of a procedural skill often takes place on an ad hoc basis. Even today, it sometimes consists of "see one, do one, teach one". The number of attempts necessary to attain competency differs from procedure to procedure[4, 5,6]. For peripheral nerve blockade training programmes extend over a period of weeks to months. Practical obstacles associated with this apprenticeship approach include the limited access to patients and availability of suitably qualified trainers

Does a valid clinical assessment tool (CAT) for ultrasound guided axillary brachial plexus block exist?

Axillary brachial plexus block is one of the most common upper limb peripheral nerve blocks performed. Optimal training in medical procedural skills, such as peripheral nerve blockade, requires valid and reliable forms of assessment[8]. Traditionally, competency in anesthesia (and other medical disciplines) has been evaluated subjectively[9]. A valid clinical assessment tool should improve the value and quality of formative and summative assessments. The objective of this first project was to develop a working, valid version of a clinical assessment tool for ultrasound guided axillary brachial plexus block. This compromised of a checklist and global rating scale. The aim was to develop a checklist in which each element represented a discrete, identifiable observable behaviour and to determine construct validity of the CAT.

2.2 Validity

Validity is defined as "the property of being true, correct and in conformity with reality"[10]. Several forms of validity have been defined. Within the literature a number of benchmarks have been developed to assess the validity of a test or testing instrument

Table 1: Types of validity

Types of validity	Definition
Face	A type of validity that is assessed by having experts review the contents of a test to see if it seems appropriate
Content	An estimate of the validity of a testing instrument based on a detailed examination of the contents of the test items
Construct	A set of procedures for evaluating a testing instrument based

	on the degree to which the test items identify the quality, ability or trait it was designed to measure
Concurrent	An evaluation in which the relationship between the test scores and the scores on another instrument purporting to measure the same construct are related
Discriminate	An evaluation that reflects the extent to which the scores generated by the assessment tool actually correlate with factors with which they should correlate
Predictive	The extent to which the scores on a test are predictive of actual performance.

All these forms of validation have merit; however, predictive validity is the one most likely to provide clinically meaningful assessment. The others focus on the assessment of the training or test rather than the clinical outcome. There is a need for improved training strategies in all types of procedural skills. With the advances in medical technology, some skills have proved much harder to teach and master. The most important questions to ask are does this device train or assess the skill it is designed to? Can it differentiate between experts, intermediates and novices?

2.3 Novice Errors

Laparoscopy is a procedure that has many similarities with ultrasound guided peripheral nerve blocks and has been studied extensively for skill acquisition and retention. A literature review was conducted to determine the factors that effect skill acquisition in simulation based laparoscopy training (Chapter 2).

During the initial data collection, it was noted that a number of novices and intermediates had difficulty keeping the needle (for performance of the peripheral nerve block) in view using ultrasound. This resulted in the potential to cause harm to the patient, causing the procedure to be "taken over" by the supervising consultant. A literature search was performed to quantify errors by trainees/ novices learning to use ultrasound for medical procedure. The article by Sites BD, et al. identified the most common novice errors, qualitatively as well as quantitatively, in ultrasound guided peripheral nerve block. [11]

2.4 Recommendations for training

The joint committee of the American Society of Regional Anaesthesia (ASRA) and European Society of Regional Anaesthesia and Pain Medicine (ESRA) recommendations for education and training in ultrasound-guided regional anaesthesia have listed tasks for performance of an ultrasound-guided nerve block.[12] Furthermore they have made "practice pathway" recommendations; involving self-practice and simulators. The top three recommendations are: 1 - visualization of key landmark structures including blood vessels, muscle, fascia and bone. 2 - Identification of nerves or plexus on short axis view. 3 - Confirm normal anatomy and recognize anatomical variations. To attain competency and proficiency in ultrasound guided regional anaesthesia the joint committee has arranged the various skill sets required into four major categories: 1 –

Understanding device operation, 2 – Image optimization, 3- Image interpretation and 4 – Visualization of needle insertion and injection of local anaesthetic solution. The image optimization (non-device related) is to learn the importance of transducer pressure, alignment, rotation and tilt (PART manoeuvre). The image interpretation is further divided into identification of the nerves, muscle and fascia, to distinguish between artery and veins, to identify bone and pleura, to identify common acoustic artefacts and to identify common anatomic artefacts and variations. The practice pathway recommendation for image optimization and image interpretation is, deliberate practice i.e. to practice ultrasound-scanning techniques on one-self, colleagues and the use of simulators. For visualization of needle insertion and injection of local anaesthetic solution, the use of simulation/ simulators has been recommended.

2.5 Simulation – recommendations

A workforce for education and training set up by the Department of Heath UK, have published, "A framework for technology enhanced learning";[13] in this document they have specifically recommended simulation as "supporting learning in a patient safe environment". Evidence has suggested simulation training helps trainees to acquire skills more efficiently rather than relying on opportunities in their clinical practice. Simulation offers the opportunity to trainees to learn in a patient free environment without the constraints of time, trainers and missed opportunity, as would apply in a clinical setting. Trainees can acquire skill sets from different simulators according to their level of training. Ideally, trainers would know how a trainee is progressing and their rate of progress on their learning curve. Even effective simulators are only part of the training solution: the simulator is one tool which is useful in delivering a curriculum.

2.6 Simulators

A literature search was conducted to identify the available simulators for ultrasound guided peripheral nerve block (Chapter Number 4). Of the available simulators the gelatine-based phantom was chosen. Based-based phantom models have been in use for ultrasound-guided procedures for a number of years. The gelatine gives a uniform appearance on the ultrasound image; hence the target being the only echogenic structure to identify in the model, thereby avoiding distraction for the novice. The problem with gelatine phantoms is the non-injectability of the phantom itself. Gelatine phantoms that have been used for research purposes have been specifically adapted to facilitate this specific problem of injectability. (Chapter Number 5) This was done with the presence of an object with a potential space that is injectable. This modification produced a phantom that can be modified according to the level of trainee, i.e. level of difficulty can be changed according to level of trainee. All the gelatine models were reproducible and were standardized as described for the projects. (Chapter Number 5)

2.7 Feedback[14, 15]

Feedback has been identified as one of the most effective determinants of learning in a simulated setting. Feedback refers to "specific information one receives about one's performance that is intended to improve future performance". There are many factors that influence skill acquisition such as the nature, timing and characteristics of the specific feedback during training.

2.8 Designing a feedback study – standardized training video

For the purpose of the feedback study, in co-operation with experts in medical education, under-graduate and post-graduate training, a training video was developed. This is in accordance with the principles established regarding design of a feedback study[16]. The script for the video was drafted and revised in conjunction with the experts. The script was enacted and the video was reviewed by the experts and changes were made accordingly, so as to optimise the learning for the participant. (Appendix IV)

2.9 Timing of feedback

Projects two and three was undertaken to determine the effect, if any, of two separate types of feedback (Chapter Number 7) and the timing of augmented feedback (Chapter number 8) on skill acquisition. For both these projects the training video and the gelatine phantom were used. The phantoms were specifically constructed in a standardized fashion as described. The types of feedback Knowledge of Result (KR) and Knowledge of Procedure (KP) were examined with a control group (Chapter number 7). The timing of feedback (Immediate versus Delayed) was examined in the third project (Chapter number 8). Immediate augmented feedback was provided using a light-box. This technique has not been described before. The study showed very surprising results in regards to feedback timing/ request and its effect of errors performed.

2.10 Live model simulator training

Using the principles of augmented feedback, its effects on bench model simulator training, the presence of a valid clinical assessment tool and from the findings of the above-mentioned projects we undertook an additional project using a live model for simulation training. This project combined the use of the checklist from the first project, the effect of augmented feedback (KP) and the timing of feedback for novices learning identification of the brachial plexus in the axilla using ultrasound. As a secondary objective we also examined the effect, if any, of the years of experience in anaesthesia on acquisition, retention and attrition of a new skill.

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3 - Review of literature of simulation based laparoscopy skill acquisition and skill retention in novices

3.1 Introduction

Laparoscopic skills are difficult to learn. Present training involves integration of service and educational activity during working hours. The reduction in working hours for trainees, translates into less time for training. Simulation has now been well established for skill acquisition for laparoscopic procedures. The purpose of this review as part of this thesis is the similarity between laparoscopic and ultrasound guided procedures, namely the 3D-2D orientation, the hand eye co-ordination required, the relatively new advances in technology and the new findings in medical education.

A comprehensive database search of PubMED, MEDLINE and Google Scholar was carried out on 30th May 2014. Studies considered for inclusion were those published after the year 2000, having 'simulation', 'laparoscopy', 'novice', 'skill acquisition', 'skill retention' or 'objective measurement of skill' in the title and abstract.

A total of 26 articles were reviewed to identify the various factors in skill acquisition and skill retention for laparoscopic procedures (Table 1).

For the purpose of this review article the literature was divided into factors pertaining to the participant and the training program (including methods of delivery). There is quite a significant overlap between the above-mentioned groups in the individual studies, as the investigators have not specifically studied just one factor but a number of factors have been identified that may have an effect on skill acquisition.

3.2 Participant factors

Aptitude and innate ability may be described as the inherent ability that a person has. This may be present at birth but not necessarily hereditary, and is something that is not established by conditioning or learning.

Studies have demonstrated a relationship between innate ability and faster skill acquisition, on a simulator[1]. The importance of innate ability and aptitude testing was found to be not in the prediction of baseline skills, but more so in the prediction of rapidity of skill acquisition[2,3,4]. Stefanidis et al, performed a battery of 12 innate ability measures (5 motor and 7 visual-spatial) and baseline testing on three validated simulators[2]. Only card rotation test correlated with baseline ability to perform on simulators. Prior exposure to videogames and billiards showed correlation with decreased training time, as did grooved peg-board, finger tap, map planning and Rey Figure Immediate Recall scores[2].

Videogames were one of the factors repeatedly identified as having a correlation with faster skill acquisition and retention not only in open surgery but also for laparoscopic procedures[2,3,5]. Better / automated hand eye co-ordination has been suggested as the reason for faster skill acquisition. This, however, did not translate into better simulator or clinical performance.

Gender has been studied, on the pretext that females generally perform worse than male. The findings of the suggested that being a female did not have an effect on the learning curve or on the scores (during training or retention tests)[4].

Interest in surgery and motivation has a positive correlation while age of trainee (including years post-training) was described as having a negative correlation with time required for skill acquisition, improvement during performances and skill retention[4,5,6]. Those medical students and interns (novices study participants) who expressed an interest in surgery demonstrated a faster learning rate and a steeper learning curve[4,5]. Older residents beginning their surgical careers were slower to develop technical skills, had slower performance and lower scores on retention tests[5,7].

Maschuw et al described a correlation between "soft skills" and skill acquisition and performance[7]. Soft skills defined and identified in this study were self-efficacy, stress-coping and motivation. Those with low levels of any of the defined soft skills predicted poor performances on simulators. A structured training program with exposure to tasks and a high motivational state was suggested as a solution.

3.3 Training program / curriculum design.

A laparoscopic technical curriculum, training novices to basic proficiency levels is superior to those that just train novices[5,8,9,10]. The difference lies in the design of the curriculum. Training to proficiency[11,12,13,14,15], deliberate practice / interval training / maintenance training[16,17,18,19,20] and feedback[21,22,23,24,25,26] have all been described as possible curriculum designs associated with faster skill acquisition and prolonged retention.

Medical education has evolved over time, training by "see one, do one, teach one" is no longer acceptable. The concept of structured training programs have been conceptualized and implemented in various specialties and sub-specialties over the past few decades and continues on. Hence the finding that a technical curriculum for achieving basic laparoscopic skill proficiency is desirable, does not come as a surprise[5,8,9]. The focus of curriculum on skills of increasing complexity demonstrated retention for al least 6 weeks post training[8]. Pre-clinical focus on basic skills and clinical phase mentoring by experts shortened the learning curve and hence may improve clinical outcome[9].

Automaticity during simulation training, even after achieving proficiency, involves longer training time. This however demonstrated superiority over proficiency based training only in skill acquisition and transfer tests[10]. This may be due to over-training. As there is skill attrition over time, over-training may compensate the loss of skill over time.

Training to proficiency has been extensively studied. Studies have demonstrated the use of variable metrics and methods for attaining proficiency. 'Fundamentals of laparoscopic surgery' program (FLS), 'Minimally invasive surgical trainer – virtual reality' (MIST-VR) and other simulators using check-lists and scores have been used by individuals to train to proficiency and also in combination with other metrics followed by retention tests at varying times [11,12,13,14].

A proficiency based simulator training using FLS was found to be feasible for training novices as compared to control group. The trained participants showed improvement in outcome measures, both post-tests and retention tests, on a simulator but this did not translate to improved operating room performance. The authors concluded that simulator performance improvement measured in minutes might not necessarily translate into better operating room performance[11].

Simulator training using FLS in combination with speed, motion and speed and motion groups, followed by transfer and retention tests, was hypothesized to improve operating room performance of novices. The speed group achieved proficiency on the simulator faster than the other groups, but the speed group also had a higher injury rate during transfer test. The authors concluded that incorporation of speed and motion metrics had limited impact on participant training, at the same time requiring more time for training[12].

Little is known about retention of skill after proficiency training. Novices were trained to proficiency using FLS and randomized to control and additional training to proficiency at one month and three months, immediately after testing. Retention tests were repeated at two weeks, one, three, and six months. There was no difference between the groups in retention tests except at six months. The authors recommended incorporation of repeated training for maintenance of proficiency[13].

Virtual reality training is known to improve operating room performance in residents[27]. Windsor, et al used the MIST-VR simulator to assess the feasibility of virtual reality for measuring skill acquisition, attrition and reacquisition of psychomotor skills in novices. Novices were trained to proficiency / criterion and tested and retested after one month using MIST-VR. Two predefined tasks were used, namely stretch diathermy and manipulation diathermy. The metrics measured were time to complete task and number of errors. They concluded that it was possible to use virtual reality to define skill acquisition, attrition and reacquisition in individual novices using predefined criterion. Furthermore they suggested that the measured metrics / parameters may be useful during repeated training sessions[14].

Mastering basic skills on the FLS curriculum first, was hypothesized to shorten the learning curve with additional benefit of reducing resource requirement. Novices who were trained to proficiency in basic skills had a shorter learning curve requiring less instruction and having a significant cost saving benefit[15].

Interval training, deliberate practice and maintenance training are known to ensure better skill retention and delay skill attrition. The ideal interval between training sessions was investigated by Stefanidis et al. The authors analyzed data from three randomized control trials involving novices, all following a similar proficiency based simulator curriculum on the FLS model. There was no correlation between inter-training intervals and change in performance. Skill attrition was similar at different training intervals. They also concluded that shorter intervals were associated with faster learning curve and improved skill acquisition[16].

Gallagher et al, analyzed data from two prospective randomized trails. In the first study virtual reality simulation training was compared in novices who received training in one day and those who received the same amount of training distributed over three days (interval training). In the second study the groups were divided into practice and no practice conditions. All subjects in both studies were trained on virtual reality simulation for the same skill attainment level. They demonstrated that those novices who received training over three days outperformed the control and single day training groups. Those novices who were assigned to practice sessions maintained or improved their skills at one week, but those with no practice sessions showed significant decline in performance at two weeks after training. They concluded that laparoscopic skills were optimally acquired on interval training but there was attrition of skills with non-use with-in two weeks[17].

De Win et al, randomized novices to six groups of identical laparoscopic training (six sessions of 1.5 hours each) delivered with different session frequency, namely a daily session, twice daily sessions, thrice daily sessions, single session alternate days, one session weekly and one session weekly with optional deliberate practice. Training was followed by retention tests at one month and six month intervals Those novices who received a daily session, performed better than the others in the post-test and at the one-month retention testing. At the six-month retention test, although the single session group performed better, the group with weekly session with deliberate practice had outcome measures that remained stable and did not demonstrate significant attrition of skill. They concluded that optional deliberate practice between training sessions reduced skill decay[18].

The reduction in working hours has had an impact on surgical training. Simulators have been suggested as a possible solution for acquisition of skills. The increasing service requirements have to be taken into consideration when implementing educational interventions. Training during working hours may be difficult. Bonrath et al, examined the difference in laparoscopic skill acquisition based on time of day. Novice subjects were permitted to choose a training session between regular working ours or after hours. All participants demonstrated improvement in outcome measures after training regardless of the timing of the training. They concluded that simulation training may be offered outside regular working hours with similar skill acquisition outcomes[19].

Maintenance training after attaining proficiency is known to delay attrition. In a study by Van Bruwaene et al, novice medical students were randomized to groups with different maintenance programs on simulators after completion of a proficiency based laparoscopic suturing training. They concluded that a maintenance-training interval of one month was ideal. In addition, they did not find any particular simulator to be superior to others. They also concluded that the performance difference between groups on the simulators did not translate into the same results in transfer tests, hence their conclusion, that transfer of training is not perfect[20].

Feedback has been identified as one of the most effective determinants of learning in a simulated setting. Feedback refers to "specific information one receives about one's performance that is intended to improve future performance"[27]. There are many factors that influence skill acquisition such as the nature, timing and characteristics of the specific feedback during training[28].

The type, quality and timing of feedback were investigated in acquisition of laparoscopic skills in a randomized control trial. A control group was compared to "buzzer" audio feedback, "voiced error" feedback and both combined. The combined group performed better than the others in terms of error corrections and correct incision. The conclusions were that type and quality of feedback have a large role in skill acquisition for basic laparoscopic surgery and serious considerations should be given for inclusion in curriculum design[21].

Video tutorials and instructor feedback impact on skill acquisition was investigated in two randomized trials by Stefanidis et al[22]. Novice medical students were randomized to watching a video tutorial once with intense feedback during training sessions, a video tutorial once with limited feedback (<10 min) or a video tutorial multiple times with limited feedback (<10 min).

FLS video-trainer model was used; all participants achieved proficiency levels. The third group required the shortest training time and number of repetitions to achieve proficiency. The combination of video-tutorials and limited feedback was found not only to be superior, but also to have an over-all cost saving benefit[22].

Knowledge of result (KR) is the information that an individual receives about the outcome of a motor skill, usually at the end of the performance. The timing and nature of KR can have an impact on skill acquisition. O'Connor et al, investigated the effect of KR and knowledge of performance (KP) on skill acquisition. They also looked at the workload of trainees during training sessions during skill acquisition. KP entails information regarding movement patterns performed by the individual and if an error occurred, how to correct it. The groups that received KR had better performance. However, the addition of knowledge of procedure feedback did not have any additional benefit. The perceived load for those who received KP was reduced[23].

Virtual reality simulation was compared to computer-enhanced feedback (Haptics feedback) for skill acquisition in a prospective randomized trial. The two groups underwent training in their respective groups and then had a post-test. Both groups demonstrated proficiency with no difference in the outcome measures. The majority of the participants had the view that haptics was an important aspect of skill acquisition. The authors concluded that novices could learn basic and complex laparoscopic skills on simulators as long as the training is objective based and ample opportunity was provided[24].

Panait et al, investigated the effect of haptics in laparoscopic skill acquisition in the context of simple and complex skill acquisition and performance by novices. Novices underwent training using FLS tasks at different levels of difficulty. In the more advanced tasks haptics allowed superior precision and faster completion of tasks. For the basic skills it did not seem to have any additional benefit. They concluded that the additional expense of haptics might be justified for advanced skill development[25].

Zhou et al, had similar findings when they investigated the effect of haptics feedback on the learning curve. They concluded that haptics feedback allowed the novices to perform consistently in the initial learning phase and shortened the initial learning curve, however the benefit at later stages of the learning curve was found to be minimal. They also suggested that haptics feedback in simulation would be beneficial for complex skill development[26].

3.4 Conclusion

Factors that affect skill acquisition in novices have been studied extensively. Both participant and training program factors have been identified. Motivation / interest in surgery by the novice proved very important. A proficiency / objective based curriculum design is beneficial, as long as sufficient time is provided. Feedback is an important component of adult learning, the timing, type and quality of feedback all have an impact on skill acquisition. Innate ability tests may be useful in curriculum designing and more importantly they should be used “not to identify who can become a good surgeon but, rather, who will need more training to become a good surgeon” [2].

Table 1: Articles with important findings / conclusions.

Authors	**Important Findings / Conclusions**
Nugent et al[1]	Positive relationship between aptitude and ability to perform basic laparoscopic skills on a simulator
Stefanidis et al[2]	One out of twelve innate ability tests (card rotation test) correlated with baseline simulator ability. Training duration and repetition correlated with prior video game and billiard exposure
Hogle et al[3]	Training to criteria showed statistical improvement in depth perception in the operative performance. There was a trend toward improvement in all other domains tested. Faster learning on a laparoscopic simulator was in those who were past or current video-gamers, but this did not translate into better clinical performance.
Kolozsvari et al[4]	There was no difference in learning plateau or rate or transfer of skill between male and females. Gender had no role in skill acquisition. Interest in surgery was a significant predictor of early performance.

Van Hove et al[5]	Participant with an interest in surgery had significantly higher scores. There was a negative correlation between trainee age and degree of improvement during training and final scores. Videogame usage correlated with significantly higher scores and better skill retention. Technical curriculum can achieve basic proficiency .
Maschuw et al[7]	Structured training enhanced performance of participants. Highly motivational states had a positive correlation. Low levels of self-efficacy and negative stress coping were associated with poor performance.
Bonrath et al[8]	A five day structured training program of increasing complexity (9 skills) may be successfully taught to novices. Skills were retained for at-least six weeks. Skill deterioration was demonstrable at eleven weeks.
Stefanidis et al[10]	Simulator training to automaticity took more training time but was superior to proficiency based training

Stefanidis et al[11]	Proficiency based training resulted in improvement in operative skills up-to 5 months. This improvement may not translate into better operating room performance.
Stefanidis et al[12]	Training to expert levels of speed and motion may have limited impact on training and requires longer training time. Speed group achieved proficiency on a simulator faster but had higher injury rate during transfer tests.
Stefanidis et al[13]	Training to proficiency (using metrics) resulted in skill retention up to 6 months, maintenance training minimized skill attrition and enhanced performance.
Windsor et al[14]	Training to proficiency using time taken to complete task and number of errors may be used in virtual reality simulator to define and measure skill acquisition, loss and reacquisition. These metrics may also be used for useful in repeated training sessions.
Stefanidis et al[15]	Training to proficiency levels in basic laparoscopic skills before more complex skills had a significant cost saving. Initial performance was better for the basic skill group.

Stefanidis et al[16]	Data from three randomized controlled trials of novices was analyzed to identify the ideal interval between training sessions in a proficiency based simulator curriculum. Skill attrition was similar at different training intervals. Shorter training intervals demonstrated a faster learning curve and improved skill acquisition.
Gallagher et al[17]	Data from two prospective randomized studies using virtual reality simulators was analyzed. Laparoscopic skills were optimally acquired on interval training but there was attrition of skills within two weeks of non-use. Interval training resulted in faster learning and better performance on the simulator.
De Win et al[18]	Participants were randomized into six training groups of identical training, divided into six sessions of 1.5 hours each, but different training frequency. Once daily sessions demonstrated faster skill acquisition. The groups with deliberate practice in-between sessions demonstrated stable outcome measures with no significant loss of skill.

Bonrath et al[19]	Time of the day for simulator training session did not demonstrate any difference in skill acquisition in any measured metrics. Simulation training may be offered throughout the week regardless of timing of day for training.
Van Bruwaene et al[20]	Maintenance training interval of one month after completion of proficiency based laparoscopic training seemed ideal. No additional benefit of different simulators was shown and no one simulator was superior over the other. The performance difference between groups on the simulators did not translate into the same results in transfer tests.
Van Sickle et al[21]	Error and voiced audio feedback group demonstrated better performance. Type and quality of feedback had a large role in skill acquisition and should be included in a training curriculum.
Stafanidis et al[22]	Two randomized trial data were analyzed. Video tutorial may be used for skill acquisition in novices. Limited instructor feedback was superior to intense feedbackduring proficiency based laparoscopic simulator training.

O'Connor et al[23]	Knowledge of result feedback for performance demonstrated a faster learning curve. The addition of knowledge of procedure feedback did not have any additional benefit. Perceived workload was reduced in the knowledge of procedure group.
Kanumuri et al[24]	Virtual reality simulation was compared to computer-enhanced feedback (Haptics feedback) for skill acquisition in a prospective randomized trial. All groups demonstrated proficiency with no difference in outcome measures. Laparoscopic skills may be acquired on simulator provided there is ample opportunity and an objective based curriculum.
Panait et al[25]	No additional benefit of haptics feedback for basic laparoscopic skill acquisition. Acquisition of complex laparoscopic skills may have benefit
Zhou et al[26]	Haptics feedback allowed the novices to perform consistently in the initial learning phase and shortened the initial learning curve and may be beneficial for complex skill development.

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4 A clinical assessment tool for ultrasound guided axillary brachial plexus block

4.1 Introduction

Axillary brachial plexus block is the most commonly performed form of peripheral nerve blockade[1]. Anatomically, the brachial plexus is easily accessible through the axilla and the different nerves are usually identifiable even in the presence of anatomical variations[2, 3]. Ultrasound guidance for nerve localization can improve success rate, shorten procedural and block onset time and prolong block duration[4]. The use of ultrasound guidance for peripheral nerve blockade requires high-level ultrasonographic equipment and intensive formal training[2]. Optimal training in medical procedural skills, such as peripheral nerve blockade, requires valid and reliable forms of assessment[5]. Traditionally, competency in anesthesia (and other medical disciplines) has been evaluated subjectively[6]. A valid assessment tool should improve the value and quality of formative and summative assessments.

Construct validity can be described as a process "to establish correlation between scores, measurements and performances that are all assumed to be related to a particular theory or construct"[7]. As more traits or performance qualities (constructs) are identified, construct validity should be updated[6]. We undertook to establish construct validity based on the assumption that a valid assessment tool can discriminate between groups known to possess different levels of expertise (e.g. novice, intermediate and expert) [6,7,9], our intent was to produce a working version of an assessment tool that was valid.

Objectives

The objectives of this study were:

i. To estimate the inter-rater reliability of a procedure specific clinical assessment tool for ultrasound guided axillary brachial plexus block in a clinical setting and

ii. To evaluate the clinical assessment tool for construct validity

4.2 Methodology

A prospective observational study was performed to evaluate a newly compiled clinical assessment tool, comprising a checklist (Appendix 1) and a Global Rating Scale (GRS) (Appendix 2).

Checklist development

Previous work at our institution resulted in development of a 35-point checklist for assessment of ultrasound guided axillary brachial plexus block[8] and of a Hierarchical Task Analysis for the procedure[9].

For the purpose of the validation study, we expanded the 35-point checklist, via expert opinion (four experts) and the hierarchical task analysis data to further define or modify the original checklist such that each element represented a discrete identifiable observable behavior. The final task specific checklist contained 63 checkpoints (Appendix 1). This expanded checklist was combined with a generic GRS with "anchors" [7,12,13] to create a clinical assessment tool specific to ultrasound guided axillary brachial plexus block.

With institutional ethical approval and having obtained written informed consent from each, 15 anesthesiologists and 31 patients were recruited; each anesthesiologist performed two consecutive blocks. The anesthesiologists were assigned to three groups based on prior experience (ever) of performing an ultrasound guided axillary brachial plexus block namely: Group 1 were (“novices”) <10 procedures, Group 2 (“intermediates”) 50 - 80 procedures and Group 3 (“experts”) >100 procedures at the time of their recruitment. The patients were all undergoing upper limb orthopaedic or plastic surgery. Patients who declined to participate or had contraindications were excluded from the study.

In the operating theatre/block room, standard anesthetic monitoring was instituted, intravenous (IV) access was secured and IV fluids (Compound Sodium Lactate) were administered to all patients. Oxygen was administered via facemask, as clinically indicated. Anxiolysis in the form of midazolam (1- 2 mg) I/V was offered to all patients. The local anesthetic solution was standardized for all participants as a mixture of 10 ml of 0.5% bupivacaine and 10 ml of 2% lidocaine with 1:200,000 adrenaline contained in each 20 ml syringe (two such syringes were prepared prior to commencing the procedure), hence was not assessed.

All participants were supervised by an expert in regional anesthesia and provided with a trained assistant. The supervising clinician was allowed to intervene by discontinuing the participant’s attempt under the following conditions:

- If the patient became hemodynamically unstable,
- Experienced pain on injection,
- Blood was aspirated in the needle,

- Greater than 15 minutes had elapsed since the first needle pass or 30 minutes of procedure time (defined as time taken from positioning of patient till end of procedure) with evidence of non-progression,
- If there was any part of the procedure that was anticipated to cause harm or deemed necessary for patient safety and patient care,
- If the participant requested that he / she could not or requested that he / she should not proceed further.

If the supervisor elected to intervene and complete the procedure, videotaping was discontinued and no further data was collected. Tasks subsequent to that point were deemed not to have been completed successfully (i.e. score of "0" assigned in calculating the checklist total). An investigator acquired a video recording of the procedure (Sony HX5V HD) using standardized shot framing and event capture. A concurrent real time recording was made of the ultrasound images using K-World Video Editing DVD Maker 2 (K World Computer Co., Ltd. Jhonghe city, Taipei County, Taiwan). The focus of the video recording was the arm / axilla of the patient, the identity of the participant and patient were masked. All the video recordings were destroyed at the end of the study to ensure the confidentiality of the patient and the participant.

Video recording was commenced when standard monitors were in place and I/V access secured and ended upon participant completion of initial block assessment. In the event that an assessment was not performed (i.e. participant did not attempt it), the videotaping ended 5 minutes after final withdrawal of needle through the skin.

The video recording was acquired in five sections namely:

i. The overview of theatre/ anesthetic room/ block room,

ii. Preparation of equipment,

iii. Positioning of the patient, participant and equipment,

iv. The procedure (block performance) and

v. Assessment of the block.

The videotapes were edited (iMovies '09 version 8.0.6) to present the procedure on one screen using picture-in-picture, with the ultrasound image on the left bottom corner of the screen and synchronized with procedure images. Two independent experts who were blinded to the level of the expertise of the participant and who had been trained in evaluation using the clinical assessment tool performed the assessment based on anonymized videos.

Other outcomes measured were i) the need to convert to general anesthesia ii) the block onset time, using sensory and motor testing every 5 minutes for a maximum of 30 minutes as given below.

Sensory block was categorized as 0 (no block) = normal sensitivity, 1 (onset) = reduced sensitivity compared with the same territory in the contra lateral upper limb, 2 (partial) = analgesia or loss of sharp sensation of pinprick or loss of cold sensation and 3 (complete) = anesthesia or loss of sensation to touch[11].

Motor block was categorized as, 0 = no block, 1 (onset) = decreased movement with loss of strength, 2 (partial) = decreased movement with inability to perform movement against resistance and 3 (complete) = paralysis[14].

Patients were considered ready for surgery when scores were 2 (partial) for both sensory and motor in all four nerve distribution areas[2]. Upon incision, the attending anesthesiologist assessed the adequacy of the block. A "successful" block was defined as one requiring no supplemental intravenous analgesia. An "adequate" block was defined as one requiring supplementation with a dose of intravenous analgesia (opioids). An "inadequate" block was defined as one requiring conversion to general anesthesia as judged by the responsible clinician[15]. Sedation was administered on patient request or at the discretion of the responsible anesthesiologist.

4.3 Statistics

SPSS (version 17) was used for data analysis and to produce the tables and charts. Checklist and GRS data were first tested for normality. Intra-class correlations (ICC) between assessors were calculated using Cronbach α. Non-normal data were analyzed using the non-parametric Kruskal-Wallis test and if significant by the Mann-Whitney U test for pair-wise comparisons.

4.4 Results

Fifteen anesthesiologists and 31 patients were recruited for the study. 30 scores were summarized using the average of the two procedures performed by each participant. One block performance was excluded because of a technical problem with the recording equipment. Participant in the novice group had a median age of 32 ± 7, intermediate 36 ± 4 and experts 41 ± 4, there were 3 females in the novice group, 2 in the intermediate group and 1 in the expert group. Procedural and block characteristics are summarized in Table 1.

No participant discontinued an attempt because of supervisor intervention. A total of ten procedures were not completed by the participants. These ten participants chose to discontinue the attempt during advancement of needle towards one of the target nerves (in nine cases, after repeated unsuccessful attempts). Six, two and one of the participants chose to discontinue their procedure after attempting needle advancement towards four, two and one nerves respectively (having been unsuccessful with all previous attempts). One participant abandoned the procedure during a very early attempt needle to advance the needle towards the first nerve. A value of "0" was assigned to all needle advancement tasks for all these ten participants.

The ICC between assessors was calculated for the checklist and the GRS scores. For checklist scores, the ICC was 0.842, 95% CI (0.695, 0.922). For GRS scores the ICC was 0.795, 95% CI (0.612, 0.897).

The checklist and the GRS scores were non-normally distributed. A total of 49 out of the 63 points in the checklist were assessed.

The median checklist scores were statistically significantly different between groups, p<0.001. The median score and range for the experts was 42.7 (46.5 - 32), for the intermediate group it was 35.0 (41.5 - 20) and for the novice group it was 21.5(41 – 17.5). When the group differences were tested pair wise, all were statistically significant (p= 0.023 for expert/ intermediate, p< 0.001 for expert/ novice, p=0.019 for intermediate/ novice). When adjustment was made for multiple testing, using Bonferroni correction to the p-value, for this variable then only the test between the expert and the novice group median was statistically significant (Figure 1).

The median GRS scores were significantly different between groups (p<0.001). The median score and range for the experts was 38.5 (40 - 27), for the intermediate group it was 25.75 (37.5 – 19.5) and for the novice group it was 19.5 (29 - 17). When the group differences were tested pair wise, all were significant (p<0.001 for expert/ intermediate, p<0.001 for expert/ novice and p=0.023 for intermediate/ novice). When adjustment was made for multiple testing for this variable then the test between the expert group and the intermediate group median and also the test between the expert group and the novice group median were statistically significant (Figure 2).

When the checklist and GRS scores were analyzed between assessors, skill-groups and subjects using a repeated measures model, no significant interparticipant or inter-assessor differences were identified. This enabled further analysis for differences between groups (expert, intermediate and novice). A simple repeated measures model of the two measures was created (Checklist and GRS). This showed very little difference between the anesthesiologists and these results were explained by the groups they were in. The only consistently significant difference was between the three skill groups.

The high failure rate of the intermediate group 60% is an unexpected finding, but correlates with the checklist and GRS scores for performance.

Table 1

Table 1: Procedural and block characteristics			
	Novice (N=10)	Intermediate (N=10)	Expert (N=10)
Completed Procedure	3/10	7/10	10/10
Conversion to GA (inadequate block)	2/3	3/7	2/10*
Adequate Block	1/10	4/10	8/10
Sensory Block onset (minutes)	20**	10	5
Motor Block onset (minutes)	25**	10	5

* 2 out of the 10 procedures completed in the expert group received 0.5% Bupivacaine and a planned general anesthetic due to anticipated prolonged duration of surgical procedure. ** A rescue block was administered at 20 minutes.

Figure1: Box-Whisker plot for objective task specific checklist scores between the groups. The middle bar in the box is the median, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value and the bottom whisker is the minimum value.

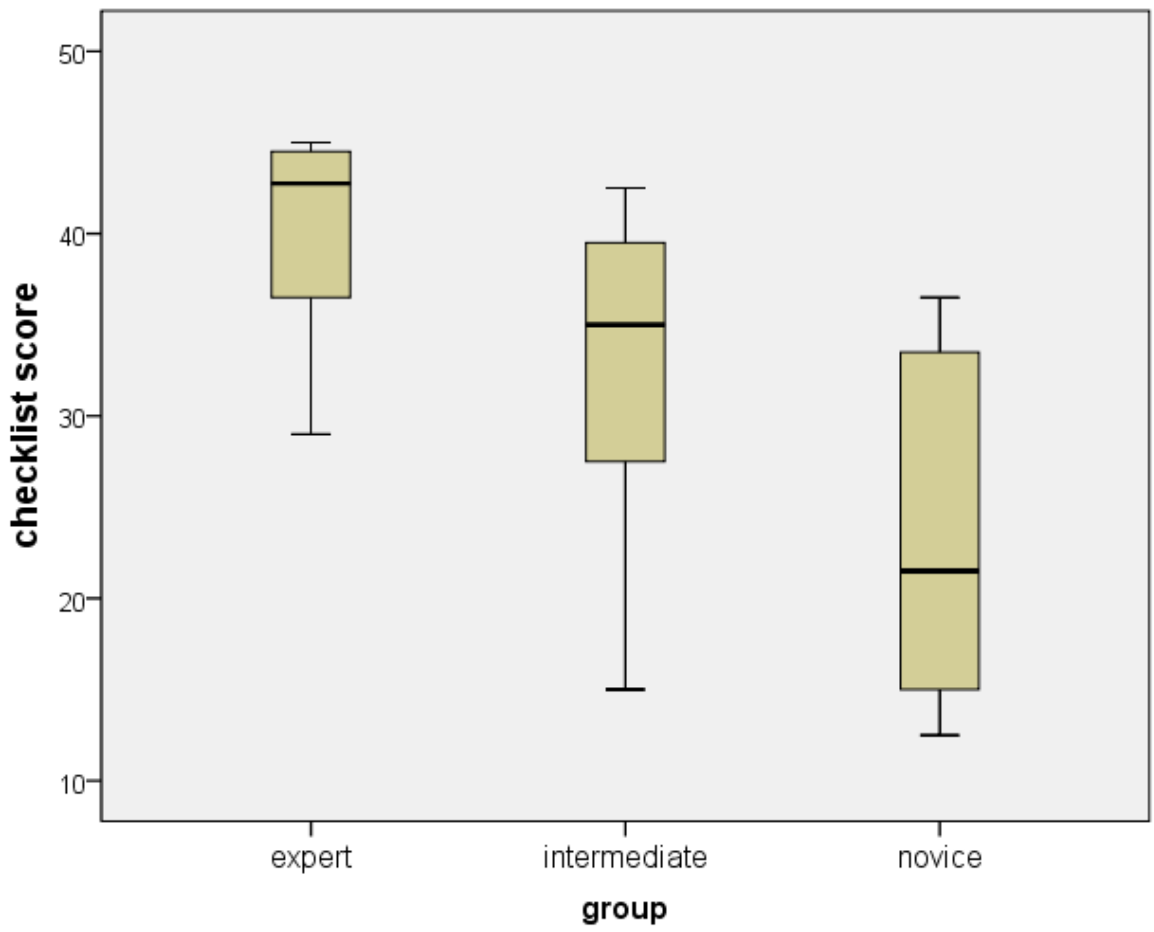
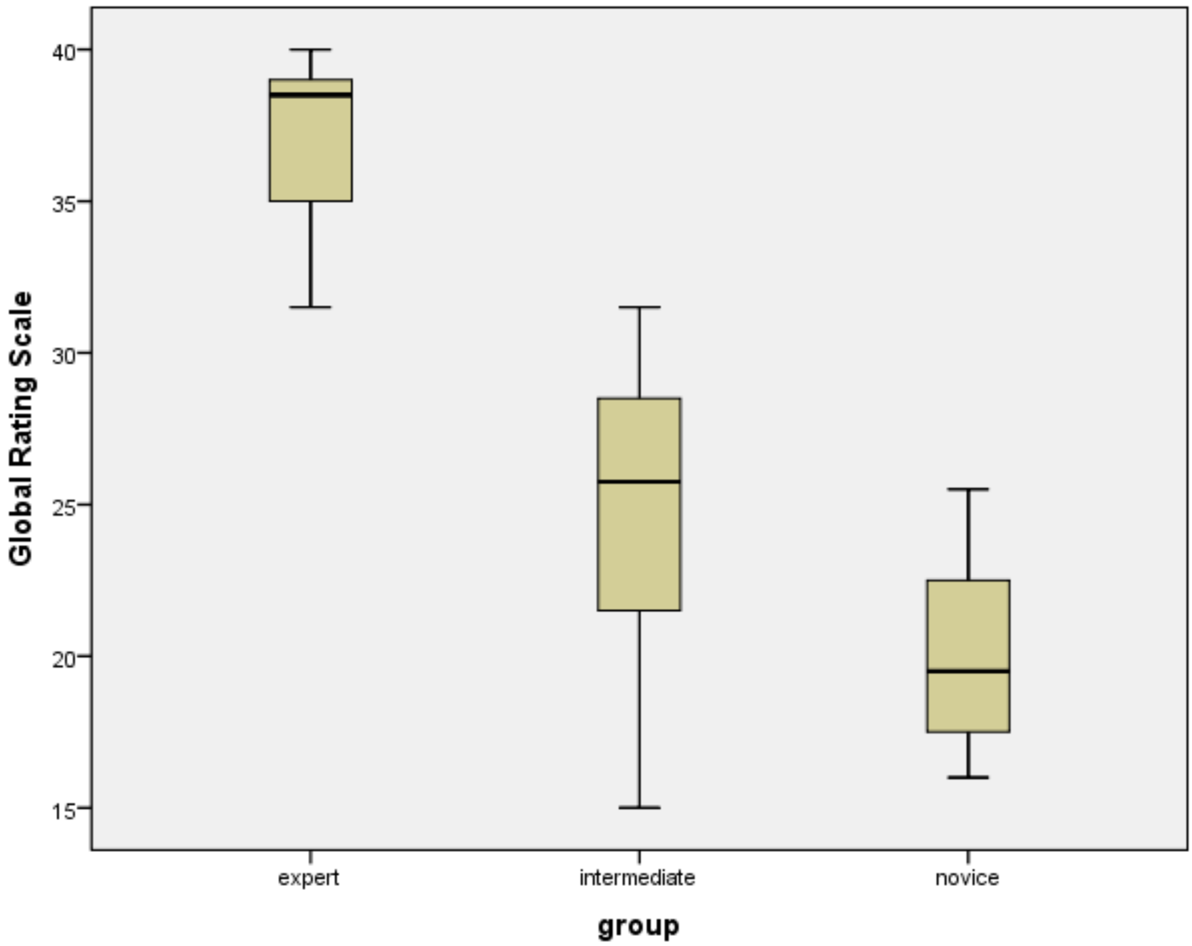


Figure 2: Box-Whisker plot for global rating scale scores between the groups. The middle bar in the box is the median, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value and the bottom whisker is the minimum value.



4.5 Discussion

The results of this study indicate that the newly compiled clinical assessment tool comprising of an objective task specific checklist and GRS are valid measures of the performance of an ultrasound guided axillary brachial plexus block.

This finding is consistent with previous findings in which a similar approach was applied to interscalene blocks[7] and to assess different level of training for performance of a procedural skill[10]. Such assessments have three goals: to optimize learning, to protect the public by identifying incompetent physicians and to provide a basis for choosing applicants for advanced training[5].

The task specific checklist was designed so that each task was a clearly identified observable behavior (i.e. completely objective). The only participant verbalization required was the identification of specific structures at the level of the axilla; all other points were clearly identified observable behaviors. The generation of the checklist has been described in the methods section.

The intra-class correlations between assessors calculated for the checklist and the GRS scores were 0.842 and 0.795 respectively, both reasonably high, hence inter-assessor assessments reliability was judged to be adequate.

With the exception of two performances by experts (time interval in-between performance was 14 days), each participant performed two consecutive blocks without undertaking any other ultrasound guided procedure in-between or receiving any feedback.

This study has certain limitations. The first six items of the task specific checklist (such as "secure IV access" and "availability of trained assistant") were excluded and were not recorded or assessed. For the purposes of our study, this enabled us to present participants with tasks specific to ultrasound guided axillary brachial plexus block in a standard clinical context. The data thus acquired was then used to evaluate the remaining checklist items (collectively) for discriminatory ability. We believe that the six omitted items may influence overall performances in a "real world" clinical environment and should be retained in a clinical assessment tool applied in that setting.

The videos were destroyed at the end of the study. This was in standing with the institutional ethics committee for anonymity of patient and participant. Each video had voices of the participant identifying the different anatomical structures in the axilla as required for the clinical assessment tool, hence the risk of loss of anonymity.

Another limitation relates to the contingency factors; in the task specific checklist. It would be deemed unethical to cause complications, in a patient and then check for the appropriate response. Also, if that complication has not occurred, it is difficult to quantify if the anaesthetist performing the ultrasound guided axillary brachial plexus block in a test setting, knows the appropriate response. We believe that the contingency factors are extremely important for teaching and for assessing of trainees.

The definition of the level of expertise according to the number of blocks performed was arbitrary. The high block failure rate (60%) in the intermediate group, was an unexpected finding, but correlated well with the checklist and GRS scores for performance. This suggests that a different definition may be needed for the intermediate group in the future.

The tool as described comprises two components, a checklist and a GRS, each of which demonstrated a statistically significant discriminatory power/value between the groups studied. Although one might agree that either alone demonstrates construct validity, we believe that the nature of the assessment information provided by each tool differs substantially. Therefore application of either checklist or GRS independently would be less valuable; particularly to enhance the value of the formative information to the learner[16].

A decision was made to assign "0" to all needle advancement tasks (in the checklist) for the ten participants who did not complete the procedure. This was based on:

i. A score of zero implied that the task had been attempted but not completed successfully.
ii. No participant, who failed to advance a needle towards any target structure (i.e. placement of needle tip in view adjacent to the target nerve), succeeded in needle advancement toward any of the four nerves.

iii. Thus we concluded that the needle advancement task was generic (i.e. not specific to a particular nerve). If a participant attempted but failed to advance towards one or two nerves, the likelihood that they would have been successful if they had persisted with this task for other nerves were very small.

We believe that this interpretation represents the most sensible approach to analysis of the data acquired on this assessment tool. It also indicates that future modification of this tool might be simplified by decreasing the number of tasks in the checklist without losing discriminatory value.

We suggest that, results of this study indicate that this tool will be useful to clinicians and educators in the training and assessment of the performance of this procedure. As more traits or performance qualities are identified, construct validity should be updated[7, 8]. In an effort to make it more clinically usable, we omitted categories of items unlikely to add discriminatory value. However we believe that further studies are required to scrutinize the decreased number (49 in total) to achieve wider acceptance, usage and to introduce weighting of the individual points. Future research should also be in developing GRS specific for regional anesthetic techniques and to validate them.

4.6 Reference

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5 Simulators available for ultrasound guided procedures - review of literature

5.1 Introduction

Simulation has been defined as “a situation in which a particular set of conditions is created artificially in order to study or experience something that could exist in reality” [1]. Simulation provides a safe and supportive educational climate [2]. Unlike patients, simulators do not become embarrassed or stressed; they have predictable behavior; are available at any time to fit curricular needs; can be programmed to simulate selected findings, conditions, situations and complications; allow standardized experience for all trainees; can be used repeatedly with fidelity and reproducibility; and can be used to train for both clinical skills and examinations [3]. Increased attention to patient care and ethical issues demands for innovation in clinical education and accelerating advances in diagnostic and therapeutic procedures have all prompted a growing interest in the use of simulators for medical training [4].

5.2 Ultrasound guided peripheral nerve blockade

The skill set associated with proficiency as defined by the American Society of Regional Anesthesia and Pain Medicine (ASRA) and the European Society of Regional Anaesthesia and Pain Therapy (ESRA) joint committee recommendations for education and training in ultrasound-guided regional anesthesia are summarized in the Appendix III. The four major categories of skill sets associated with proficiency are (1) understanding device operations, (2) image optimization, (3) image interpretation and (4) visualization of needle insertion and injection of the local anesthetic solution. Of these, image optimization and image interpretation can be practiced on one self, colleagues and appropriate animal or cadavers models. Visualization of needle insertion and injection of local anaesthetic solution can be practiced using simulators and phantoms [5].

Deliberate practice entails the repetitive performance of carefully defined cognitive or psychomotor skills in a focused domain, coupled with rigorous skills assessment that provides the learner with specific, detailed feedback, to enable sustained improvement in performance [6]. A common feature of experts, in addition to gaining experience, is that they have performed years of deliberate practice. The attained level of expertise in the performance of sportsmen and musicians is related closely to the time devoted to deliberate practice [7, 8, 9]. Experts deliberately construct and seek out training situations to attain desired goals that exceed their current level of performance and that often require problem-solving and better methods of performing the tasks [7, 10].

Simulation provides an opportunity for deliberate practice with immediate feedback that is not usually available in the operating theatre. Growing evidence demonstrates that simulation has a valuable role to play in the acquisition of procedural skills[11]. A simulator is simply a device, whose application determines its utility.

This piece of work describes the simulators currently available for learning ultrasound-guided procedures.

5.3 The ideal phantom [12]

Characteristics of the ideal phantom are summarized in Table I. Additional features not presented in the table are as follows. Approximate matching of the velocity of sound is desirable as this determines distances in the ultrasound image; however close matching of the attenuation of the medium with tissue is otherwise unnecessary. The targets must be clearly distinguished from the surrounding medium in the ultrasound image, but the difference in acoustic impedances should not be so great as to produce reverberations. The level of difficulty/complexity should be amenable to change according to the level of the trainee or requirement of the trainee [12].

The advantages and disadvantages of each of the different phantoms available or reported in the literature are summarized in Table II.

Table I

Characteristics of the ideal phantom for ultrasound guided procedures
The ideal phantom should: • Reproduce the texture and resistance of human tissue • Inhibit sideways movement of the needle • Have sufficient ultrasound penetration to enable identification and location of targets to a depth of 10cm • Be easily repairable, from the damage caused by needle insertion • Have targets that must be clearly distinguished from the surrounding medium in the ultrasound image • Have targets that do not corrode over time • Identify clearly to operator when contact has been made by needle with the target • Be affordable • Have a long shelf life • Have no infection issues • Be easily transportable • Be composed of non-perishable material • Have different levels of difficulty/ complexity that can easily be changed • Be easily reproducible

5.4 Animal Models

5.4.1 Turkey and chicken breast models [13]

Turkeys are purchased whole and the legs and wings removed. The breast is left intact, attached to the sternum. A space is bluntly dissected between the pectoral muscles beginning at the cavity of the turkey on the side opposite the sternum, at the edge of the rib cage. Small Spanish pimento-filled olives are placed between the muscles in the turkey breast while it is submerged in water. The target is identified as the pimento within the olive (mean antero-posterior diameter 3 mm; mean width 3 mm; mean length 10 mm). Turkey and chicken breast may be used with a number of targets that can be imbedded using dissection techniques.

Advantages include wide availability, realistic feel of the tissues (haptics), presence of blood vessels, bones and nerves and the possibility of imbedding targets in the model. These allow a realistic feel of tissue handling and ultrasound image acquisition for the learner.

5.4.2 Porcine joint/ shoulder or leg of lamb with metal rod [14, 15]

In this described model the tendon is used instead of nerve because nerves are generally not available for purchase. A piece of pork shoulder, preferably with the humerus attached, is carved to approximately 20 x 12 x 8 cm (length x width x height) in dimension. After removing the skin, the pork specimen is deodorized by soaking it in 20 to 30 mL of 70% alcohol inside a plastic bag for 8 to 10 hours at 4°C. A solid metal or plastic rod approximately 1.5 cm in diameter is used to pierce through the muscle layers and create a tunnel approximately 3 cm from the surface. A bovine tendon approximately 8 cm long and 1 cm in diameter is then pulled inside the tunnel. The whole phantom is then wrapped up in a transparent film, reinforced exteriorly by a surgical paper towel, and stored at 4°C until use.

A fresh leg of lamb weighing 1.5 to 2.5 kg, may be acquired at the local halal butcher at a price of 20 to 30 Euro. It must contain a heel (Achilles) tendon, which is then softened by wrapping a gauze swab soaked in distilled water around it. The tendon is then cut off and used as a nerve. A 40-cm-long blunt metal rod is threaded between the muscles of the posterior thigh, with the intent of separating but not penetrating the muscles. The end of the tendon is sutured to the wide end of the metal rod and pulled inside the leg, so that only nylon sutures are visible outside. This model has muscles, fascia, and bone. The tendon has the echographic appearance of a nerve, the needle approach is visible just as in humans and injection of a normal saline solution is visible, albeit for a shorter time than in a patient. Injection of fluid inside this nerve model is also possible using high pressure and shows disruption of fibers. Short- and long-axis nerve scans, in-plane and out-of-plane needle insertion, visualization of a catheter advancement, and fluid injection through the catheter are all feasible.

Advantages include low cost, wide availability, ultrasonographic appearance of muscles and bone, and the embedded tendon mimicking a nerve appears predominantly hyperechoic. The “fibrillar pattern” seen on ultrasound resembles nerve fascicles. The tendon diameter may be varied and may be used for multiple needle passes. Needle-track artifacts are less likely to show after repeated needle punctures compared to a gelatin-based phantom, and saline injection around the target simulates a local anaesthetic injection.

Disadvantages of animal phantoms in general include high expenses, the issue of infection control, a short shelf life of a few days, the need for refrigeration, the time needed to prepare the model with the targets and the possibility of air trapping while preparing models [13, 14, 15].

5.4.3 Tofu model [16]

The tofu model is a simple, inexpensive, portable and variable complexity design. It allows novice learners the opportunity to practice target localization and ultrasound-guided needle advancement towards a target. Targets structures (wood and wire) can be inserted[16]. The focus of this model is not on the skill of anatomical scanning, but rather to gain the technical skills necessary to direct the needle toward an established target, which is confirmed by both ultrasound image and tactile sense of needle contacting the target.

Advantages include easiness to construct including embedded targets, low price (although this may vary between countries), suitability for novices learning hand-eye co-ordination.

Disadvantages include availability of extra firm tofu (as the normal tofu easily breaks down on pressure for insertion of targets), too uniform an echogenic appearance, requirement for storage in a refrigerator, the seepage of water from the model over time, its non-injectable nature. In addition, the model constitutes an excellent growth medium for bacteria, hence raising infection control issues.

5.4.4 Blue Phantom [17]

The blue phantom is a commercially available product. It has been used for simulation for intravenous access as well as for other parts of the human body. Its use in regional anaesthesia training is limited.

Advantages include portability, a large scanning surface, long shelf life and the fact that it is reusable. The developers claim that in can be injected into as well.

Disadvantages include expense, preformed with fixed targets, additional targets cannot be imbedded, needle tracks are visible for a while (has a memory) and non-tissue like haptics.

5.4.5 Gelatin[12] and agar based[18] models

Gelatin based models have been used by radiologists for learning and teaching of ultrasound guided procedures. The models are easily constructed by using basic kitchen utensils and have a lot of characteristics of the ideal model. Like the tofu model, the gelatin and agar based models are suitable to learn hand-eye co-ordination. Any number of targets can be imbedded into the model, including starch blocks, raisins, peapods, wires, wood, tubing, etc.

Advantages include low price, wide availability of ingredients, can be prepared with readily available kitchen utensils, portability, a large scanning surface, the possibility of embedding any number of targets. The model can be made clear or colored, of any size and shape according to the container used and is easily reproducible. Once used, the model can be disposed of safely as it does not contain any biohazard material. The gelatin model can be stored in the fridge for up-to two weeks if an anti-septic is used when preparing the model. Over time it seeps water much like the tofu model mentioned above.

Disadvantages pertain to the fact that for learning of regional anaesthesia, gelatin and agar based models pose problems with the haptics. Depending on the concentration used, the models can be easily damaged and the sideways needle movement may not be inhibited. Models are transparent unless color is added and have a uniform appearance on sonography unless additives (husk, corn flour, thickening agent) are used. Needle tracts are visible and may be mistaken for the needle. These models cannot be injected into unless it is in the target or if a potential space is made available. Agar may not be easily available in certain parts of the world.

5.4.6 Premisorb based model [19]

This model can be constructed using materials available in the operating theatre complex. These include a clean used 500-mL plastic bag of IV fluids, a rubber stopper from the bag of IV fluids, a bottle of Premisorb, a piece of tape, a piece of foam padding, and scissors. Premisorb is a solidification product designed to absorb and encapsulate blood vomit or any fluid with at least 6% water content[20]. Premisorb in water creates a semitransparent gel-like material with an ultrasound image similar to human muscle tissue. The imbedded blue color foam padding is easily visible through the transparent plastic bag and produces a relatively hyperechoic target comparable with a nerve on the ultrasound image. The gel-like semisolid material seals needle holes and also allows the instructor to move the simulated nerve target to different depths or positions in the bag.

Advantages: it is inexpensive, nonperishable, reusable, and easily transportable.

Disadvantages: Premisorb is not freely available. Furthermore, direct contact with the skin and chemical exposure may pose safety issues, such as contact dermatitis. Of note, the manufacturers do not recommend direct skin contact. As it is water based, haptics may not resemble those of human tissue and the placement of the target may be difficult.

5.4.7 Silicone based model [21]

The silicone-based model incorporates electrical components and equipment for pulsatile flow. The novelty of this model is that it produces a sound when the needle makes contact with the target structure. The model comes preformed with a structure that shows pulsatile flow.

Advantages include no infection issues, a long shelf life and its transportability.

Disadvantages include persistence of needle tracts after multiple uses, a small surface area for scanning, the high market price. Other disadvantages are the preformed shape and size, the embedded target structure and the need for electronic/battery power.

5.4.8 Cadavers [22]

Cadavers are useful tools for practical training in regional anaesthesia. Specific elements that may be taught utilizing cadavers include probe handling on irregular surfaces, needle- probe alignment, sono-anatomy and needle tracking to target structure[23].

Disadvantages include the limited availability of cadavers, the need for ethical approval, the cold storage needed, infection issues and the absence of pulsatile flow.

5.4.9 Computer based simulators [24]

Computer based high fidelity simulators have been used for training with ultrasound-guided procedures but the obvious problems are the costing, the need for IT support, the altered haptics.

Advantages include the absence of infection control issues, the possibility of altering the level of complexity/ difficulty. The machines can be set up in a non-clinical setting such as a training room. The simulator may be available any time of the day or night. Additional advantages include the size of the machine and the validity of the machinery and programmes.

Table II

Simulators currently available for training in US-guided procedures		
Simulators	Positive Points	Negative Points
Turkey and chicken breast model[13], Porcine shoulder[14], Lamb leg with metal rod[15]	Realistic feel for tissue Natural structures present, can embed targets	Short shelf life Infection risk Messy Expensive Need preparation time
Tofu model [16]	Simple, affordable, portable, degree of complexity can be changed, target can be inserted but not embedded	Not easily available, breaks down on pressure, Cannot embed target, Seeps water over time. Needs refrigeration Too uniform in echographic appearance Not injectable Infection issue

Blue Phantom[17]	Portable Realistic No infection issues Large scanning surface May be possible to inject, Long shelf life Reusable	Expensive Preformed Cannot embed additional targets Fixed targets Needle track Non tissue like haptics
Gelatin based model[12]	Cheap, Portable, Large scanning surface Injectable targets can be embedded Appearance and shape can be modified Transparency can be changed Reproducible	Needs preparation time Needle tracks after every use, Shelf life of 2 - 3 weeks Uniform appearance Breaks on excessive pressure
Agar based [18]	Targets can be placed Level of difficulty may be increased Portable	Growth and transmission of infection as organic base and a culture medium Agar is not easily

		available Memory (needle tracks) after each needle pass Need for preparation time May be expensive according to geographical location
Premisorb based[19]	No infection issue Cheap Portable	Availability Dangers of chemical exposure Haptics may be inaccurate Target placement may not be reproducible
Silicone based	No infection issue, Produces sound on needle contact with nerve structure Flow identifiable via Doppler	Price has not been quoted Memory after each needle pass Little space for needling

Cadavers[22, 23]	Anatomical relevance	Infection issue, Availability Storage problems
Computer [24]	No infection issues Level of difficulty/complexity may be changed	Expensive Need for IT support Not easily portable Inaccurate haptics

5.5 Current deficits

All of the described simulators have been used or are being used for training, not only of regional procedures but also for other procedural skills (vascular access, core biopsy, etc). Little is known about the validation process.

Validity is defined as “the property of being true, correct and in conformity with reality”[25]. Validity is not a simple notion, it is comprised of a number of first principles. A number of benchmarks have been developed to assess the validity of a test or testing instrument (Table III).

All these validations have merit; however, predictive validity is the one most likely to provide clinically meaningful assessment. The others focus on the assessment of the training or test rather than the clinical outcome. There is a need for improved training strategies in all types of procedural skills. These skills have proved much harder to teach and master. The most important question to ask is does this device train or assess the skill it is supposed to?[25].

5.6 Skill generalization, skill transfer and skill acquisition

Skill generalization refers to the training situation where the trainee learns fundamental skills that are crucial to completion of the actual procedure. Skill transfer refers to a training modality that directly emulates the task to be performed in vivo or in the testing condition[25]. For skill generalization the simulator should teach basic psychomotor skills fundamental to performing a basic procedure as well as some skills required for more challenging procedures. For skill transfer the simulated procedure should look and feel similar to the actual procedure and should train skills that will directly transfer to the performed procedure.

Psychomotor skill acquisition is an essential pre-requisite for performance of a safe procedure. Traditionally, procedural skills have been acquired by trainees through an apprenticeship model. Trainees observe the supervisors and perform under their supervision until "mastery" has been achieved. With the reduction in training hours and hence patient exposure, the supervision and number of procedures performed during training have dropped drastically. The issues of patient safety, accountability in medical performance, professional requirements for uniformity in training and cost effectiveness in training arise with this reduction in trainee-patient exposure. The most reasonable solution seems to be simulation [25].

5.7 Future direction

There is a need for a safe, stress free environment for trainees for skill acquisition, generalization and transfer via deliberate practice. The reduction in training opportunity has a huge impact on skill acquisition. The numbers of simulators are ever increasing. The increase in fidelity is associated with an increase in cost. Trainees can acquire skill sets from different simulators according to their level of training. The trainers need to know how a trainee is progressing and where they are on their learning curve. Simulators are only part of the training solution confronting residency programs and credential committees around the world[25]. The true benefit of a simulator can only effectively be realized if they are integrated into a well thought out curriculum.

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6 Development of Standardized Phantom Model

6.1 Introduction.

It is recommended that training in ultrasound-guided regional anesthesia should address four skill sets (1) understanding ultrasound image generation and device operation, (2) image optimization, (3) image interpretation and (4) needle insertion and injection[1]. These skills can be acquired through attending peripheral nerve block courses, practicing ultrasound-scanning techniques and learning sono-anatomy by imaging one-self and colleagues, and practicing needle manipulation using simulators and phantoms[1]. Sites et al have identified errors characteristic of novice learning of ultrasound-guided peripheral nerve blockade; the most common of these is "advancement of needle when the tip was not visualized"[2].

Simulation is an integral part of training, assessment and research in aviation, nuclear power and the military[3] and is likely to become a mandatory component of training of health professionals[4]. Simulation has a key role to play in enabling development of medical skills from novice to expert[4]. The use of simulation models has been shown to improve skills and success with ultrasound-guided procedures[5]. A phantom may be described as any media other than live human tissue that can be used for research or training. Phantoms provide a (generally) simple tool which one can use to aid learning of the skills of ultrasound-guided needle placement, before clinical use, with the aim of decreasing the incidence of complications[6].

In this article, we describe a gelatine-based phantom that can be used to identify most of the common "novice errors" and to facilitate learning of the relevant skills. This phantom can be constructed from low cost, readily available items, is re-usable and can be modified to present a learner with greater degrees of difficulty as he/she progresses in training with no additional cost.

6.2 Methods.

Phantom construction.

The equipment required to construct the phantom are (1) one microwave safe bowl of > 500 ml capacity; (2) Cling film (e.g. TESCO cling film microwave safe, TESCO, UK) 35cm wide or greater; (3) a jug (microwave safe), approximately 1 litre capacity for measuring and mixing; (4) hot water (boiling to tepid) 500 mls; (5) Gelatine (such as Dr. Oetker Gelatine, Dr. Oetker Ireland Ltd, Dublin 24, Ireland, www.oetker.ie) 6 sachets (70 gms); (7) magnetout peapods; (8) syringe 5ml; (9) 24 G needle (orange); (10) 0.9% normal saline 5 mls. (11) microwave; (12) spoon; (13) Blue food colour (Dr Oetkers (UK) ltd. Leeds England www.oetker.co.uk); (14) Dettol antiseptic liquid (Reckitt Benckiser Healthcare (UK) Ltd. Hull, UK).

First, spread the cling film (approximately 30 cms), on a clean table, and fold it on itself to create a double layer. Press firmly to remove all air bubbles. Line the inside of the bowl such that all sides are covered with the cling film. Pour 500 ml of water into the measuring jug, add the gelatine sachets and mix, using spoon until dissolved. Add one spoonful (5 mls) blue food colour and one ml of Dettol to mixture. Pour 300 mls of this mixture into the cling film lined bowl.

Select an undamaged magnetout peapod. Use the 5ml syringe (filled with 0.9% normal saline) and needle to pierce one end of the magnetout peapod. Inject approximately 1 ml 0.9% normal saline into the peapod to expand and separate its internal walls. Withdraw the needle and place the prepared peapod in the bowl with the gelatine. Wait for gelatine to set with the magnetout peapod in-situ.

Once the gelatine in the bowl has set, place the measuring jug in a microwave and heat until the remainder of gelatine liquefies (depending on settings, 600-800 W is standard, usually 30 seconds to 1 minute will suffice). Pour the remainder of the gelatine into the bowl with the set gelatine to form another layer, so as to incorporate the prepared pod completely in the centre of the completed phantom. Set the preparation aside until the gelatine has hardened (refrigeration can also be used). Once the gelatine has hardened, lift the phantom from bowl using the cling-film and fold cling-film over the top. Turn the model upside down (Figure 1 A) to use for scanning and needle manipulation.

Re-using the model.

Once a needle has been placed in the phantom, it retains the deformation (memory) caused by the needle's advancement. Line the inside of the bowl with cling-film as described; remove the model from the used cling film and place it in a bowl. Place the bowl (with new layer of cling-film) in a microwave and heat (on high setting) for 10 – 15 seconds, longer for lower settings. This reheating process liquefies the gelatine enough for the needle track to disappear. Set the bowl aside until the gelatine hardens and the phantom is ready to be used again.

6.3 Discussion

The shape and size of the model can easily be modified during its preparation. Once set, it is quite robust and easy to transport between teaching locations.

The double layer of cling film on the phantom provides the user with reasonably realistic "feel" of a needle piercing skin. The gelatine provides an anechoic background, which enhances needle visibility. The most common error by novices is loss of needle visualisation; we believe that, in clinical practice, this may be due to the distracting presence of other echoic structures. For novices to learn this critical skill, it may be advantageous to remove such distractions.

As we have described its preparation, the phantom is opaque due to inclusion of the blue colouring. If the colouring is omitted, the target can be seen in daylight and be clearly identified. When the phantom, as described, is trans-illuminated (using a light source underneath) the target can be identified as well. We have found this to be a very useful means of providing real time, immediate or early feedback as a novice practices probe-needle-target orientation (Figure 1 B and C).

The target structure (magnetout pea) inside the pod is reasonably similar in appearance to a target nerve; the peapod wall offers resistance to needle advancement (a "pop") similar to that of a fascial layer and allows aspiration and injection of fluid into the pod. Hence the performer can see injectate spread around the target structure (Figure 2). This quality of this phantom differentiates it from the other available non-animal tissue phantoms, in that one can visualise injection and spread of injectate relative to a target structure. This is so because the peapod limits the unrestricted dissipation of injectate while retaining it within expansible walls (Figure 2 C). Although this is an advantage, it is also one of the limitations of the phantom. It is possible for a novice to identify correct placement of the needle tip (by feeling the "pop") despite having lost visualisation of the needle tip.

The needle track (memory) is removed by reheating the phantom (as described).. This makes this phantom ideal for research purposes as a "standardised" phantom can be re-used with no changes in the structure or position of the target or the phantom.

The phantom can be modified to present the learner with tasks of greater levels of difficulty. This is achieved using either strips of cling-film placed in the phantom to represent fascial planes or by adding flour or husk to the preparation to increase the echogenicity of the phantom or both. A "blood vessel" can be represented by incorporating a length of intravenous tubing in the phantom and attaching it to a roller infusion pump. The roller mechanism of the pump replicates pulsatile flow and can be identified using colour doppler.

6.4 Conclusion

Based on our routine use this phantom, we believe it to be an inexpensive and effective tool to facilitate the learning of ultrasound -guided peripheral nerve blockade by novices. Many of the errors characteristics of novice learning can be reproduced using the phantom and therefore a novice can learn or be taught to avoid them. Such a model may be useful for those providing training or courses in ultrasound guided peripheral nerve block. We believe that it will be worthwhile to formally examine the educational value of using this phantom in a training programme for novices.

Figure 1:

A) shows the ultrasound probe, phantom and needle; B) shows the ultrasound probe, phantom, needle and the target structure (via Transillumination); C) shows the phantom, needle and target structure without the ultrasound probe, the visible target structure may readily be identified by the novice trainee.

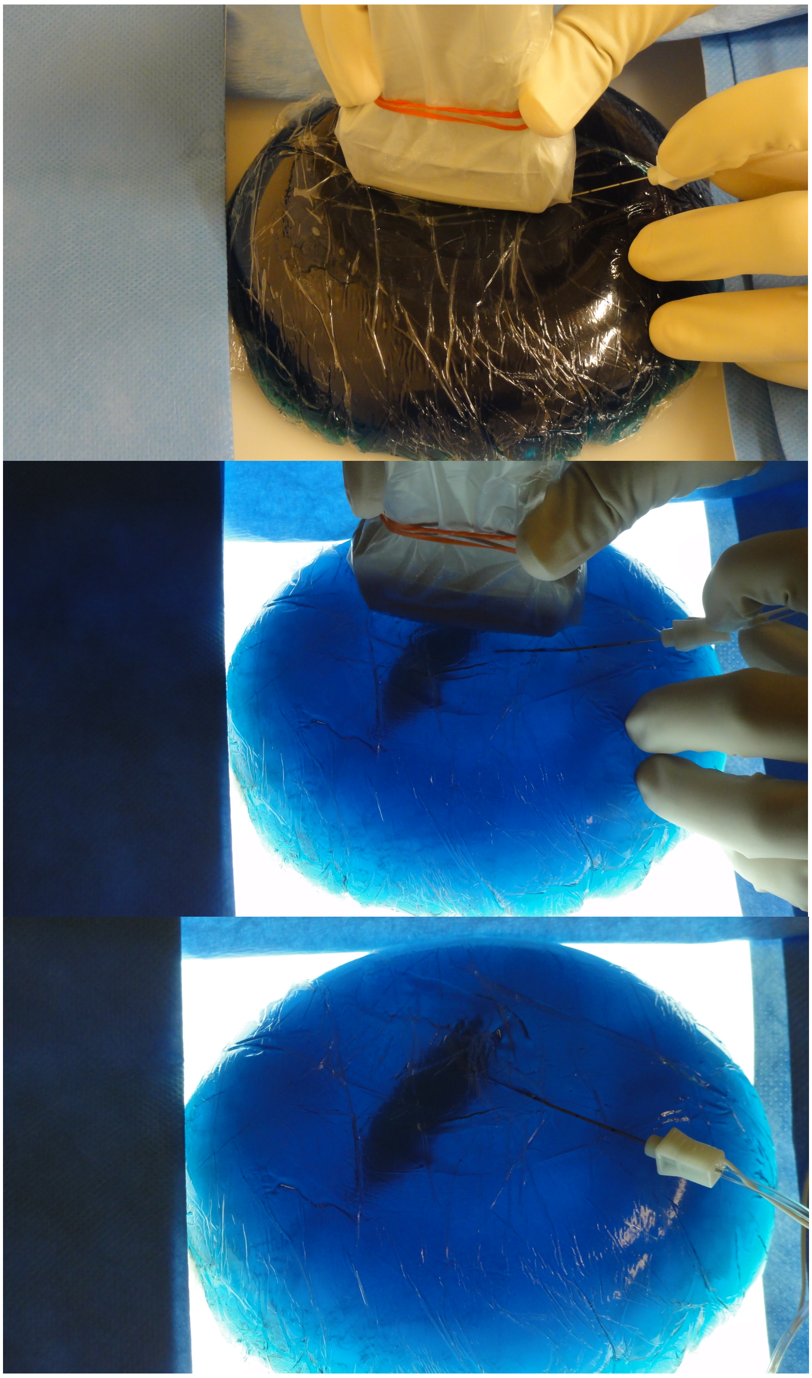
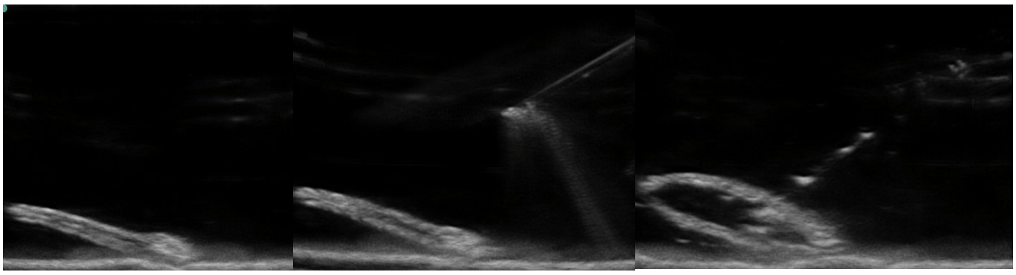


Figure 2:

Pictures from the ultrasound machine (Sonosite M-turbo) A) shows target; B) shows needle tip and shaft approaching target structure; C) shows the target structure expanded with fluid and also shows a needle tract memory in the phantom.



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7 Effect of feedback content on novices' learning ultrasound guided interventional procedures

7.1 Introduction:

The feedback provided to a learner who is attempting to acquire a new motor skill is an important determinant of learning[1]. In the context of motor learning, the content of feedback can include information about the outcome (termed "Knowledge of Result" KR) or about the quality of the movement (termed "Knowledge of Performance" KP) or both[2, 3]. KR refers to a pre-defined outcome measure (e.g. success or failure, proximity to a target). KP refers to the movement patterns observed. For instance, an instructor may point out errors made in performing specific steps of the procedure[3].

In general, the learning of motor skills benefits from augmented feedback.[4, 5] Recent studies have demonstrated improved performances in clinical skills and simulator training secondary to augmented feedback[3, 6]. The nature, timing and characteristics of feedback that will benefit those learning clinical skills are largely undetermined.

The key requirement for successful regional anaesthesia is to ensure optimal distribution of local anaesthetics around nerve structures. This is most effectively achieved under sonographic visualization[7]. Ultrasonographic guidance is associated with a greater rate of block success, shorter procedure times, faster onset times, longer block duration and appears to reduce the risk of inadvertent vascular puncture during block performance.[9] Ultrasound imaging requires acquisition of a new set of skills related to device operation and cross-sectional anatomy, which are likely to challenge the novice[8]. The most common novice error appears to be advancement of the needle when the tip is not visualized when attempting the “in plane technique”[8]. To date, limited evidence exists regarding the learning process and skill development required to conduct safe and effective ultrasound-guided regional anesthesia[8, 10].

Objective

The primary objective of this study was to compare two forms of feedback (based on content KR and KP) on novice learning of in-plane technique for ultrasound-guided interventional procedures.

The secondary objective was to compare the forms of feedback (and versus control) in terms of retention of improved performance 24 hours after initial learning.

7.2 Methods

With institutional Ethical approval and having obtained written informed consent from each, 30 fourth year medical students of University College Cork (UCC) were studied. A letter of invitation was sent to all fourth year medical students. Participants had no previous training or experience of performing ultrasound guided procedures.

For each participant, the following data were collected: age, gender, visual acuity, dominant hand and videogame use. All participants, if needed, wore corrected lenses.

Each participant received a video tutorial on ultrasound and the procedure to be performed.

Training Video Development

The video script was drafted and revised in consultation with members of the Medical Education Unit at UCC Appendix IV.

The script was enacted and video recorded using Sony HX5V HD (Sony DSC-HX5V HD, SONY Corp, China) and using standardized shot framing and event capture. A concurrent real time recording was made of the ultrasound images using K-World Video Editing DVD Maker 2 (KWorld Computer Co., Ltd., Jhonghe City, Taipei County, Taiwan). The videotapes were edited (iMovies '09 version

8.0.6, video editing software, Apple Inc 2010, Mac OS X Version 10.7.2, US) to present the procedure on one screen using picture-in-picture, with the ultrasound image on the left bottom corner of the screen and synchronized with procedure images. The duration of the final tutorial video was eight minutes.

The tutorial video was independently evaluated by five consultants with extensive and current experience in medical student teaching and separately by five consultants with expertise in regional anaesthesia for content validity. It specified the five tasks that each participant was asked to perform (Table 1). The tutorial was delivered individually to each participant in a standardized environment using Philips SHB6110 wireless-blue-tooth headphones (Philips. The standardized environment was set up adjacent to the operating theatre block at Cork University Hospital; its configuration and the equipment used were identical for the duration of the study. The ultrasound machine (M-Turbo Ultrasound System, SonoSite Inc, Bothell, WA 98021, USA; with a linear probe 6 – 13 MHz) was positioned at the back of a trolley holding the phantom model.

Phantom Model Development:

The phantom used was a gelatin-based model.[11] All models had standardized dimensions, 3.5 cm deep with target structure embedded between 0.5 – 1 cm. The target structure was a bean pod (magnetout bean). The ultrasonographic appearance of the bean in the pod is similar to a nerve/ nerve root and the wall of the bean pod has the tactile feel and appearance of a fascial place. The bean pods were prefilled with one ml of 0.9% normal saline to expand and form a potential space before setting in the phantom. All of the models were opaque, such that the target structures were not visible to the naked eye.

Participants were randomly allocated to one of the groups:

i. Group C (Control): participants received no feedback.

ii. Group KR: participants were provided with feedback at the end of each series of tasks in the form of imaging time, needling time, performance time, number of needle passes.

iii. Group KP: participants were provided with feedback at the end of each series of tasks in the form of identification and corrections of the errors made and advice on how to avoid them in future.

The KP feedback was standardized in video format. The predefined errors and standardized advice underwent the same process as described above for the training video.

Table 1: Tasks and Task Definitions		
Task 1	Orientation of the probe	To apply ultrasound gel to the probe and the probe to the model. To verify, verbally, which side of the ultrasound probe corresponded to the blue dot on the ultrasound screen. To confirm that the right side of the screen represented the phantom structures on the participants right side
Task 2	Identification and depth measurement of the target structure in the phantom model.	To scan the model using the ultrasound probe; to identify the target structure in the model in a cross-section view; to verbally confirm the location and depth of the target structure with the investigator
Task 3	Use of color-flow analysis to rule out the possibility that the structure was not identified as a blood vessel	To verify that the target structure was not a blood vessel, by using the color-flow function appropriately
Task 4	Insertion of the needle using the in-plane technique towards the target structure,	To insert the needle using in-plane technique and to advance it towards the target structure, keeping the shaft and tip of the needle in view throughout. To

	maintaining the shaft and tip of the needle in view at all times	position the needle tip above the target structure
Task 5	Aspiration and injection of fluid around the target structure under US guidance, keeping the needle tip in view at all times	To aspirate and then inject keeping the needle positioned immediately above the target structure. To demonstrate the spread of injectate around the target structure using real time US

All participants had access to the video tutorial for a period of up to 60 minutes, deemed the Learning Phase (LP), during which they attempted to perform the each set of tasks (Table 1) five times. Each set of task was deemed as a “Trial”. The purpose was to achieve three learning outcomes, namely:

i. Minimize imaging time: (defined as the interval between contact of the ultrasound probe with the model and the acquisition of a satisfactory picture)[12].

ii. Minimize needling time: defined as the interval between the initial needle insertion and withdrawal of needle from the model[12]

iii. Minimize performance time: defined as the sum of imaging and needling times[12]

Standardized advice was developed for certain of the pre-defined errors (those for which the means of correction was not immediately obvious to the participant) Table 2.

Table 2: Error and Advice	
Non-orientation of the probe	The video demonstrates to the participant the importance of orientation of the probe and how to perform it.
Incorrect orientation of the probe	The video demonstrates to the participant to turn the US probe 180 degrees or to insert needle on the opposite side of US probe with respect to original insertion site.
Needle advanced while not visualized in the longitudinal plane of the ultrasound image.	The video demonstrates to the participant how to insert the needle in the longitudinal plane; and explains the risks of advancing a needle without visualizing both shaft and tip. The video also demonstrates how to move or angle the US probe to search for the needle.
Insertion of the needle in the axial plane of the ultrasound beam.	The video demonstrates that a 22- gauge needle visualized on axial section appears as small dot that is difficult to analyze for anatomic location the correct performance was also shown.
Failure to recognize the needle had contacted the endpoint	The video demonstrates to the participant that he or she has to watch the ultrasound image as the needle approached the target.
Failure to aspirate before injection	The video demonstrates to the participant the importance of aspiration, to verify whether the

	needle tip is intravascular or not.
Failure to recognize inappropriate spread of injectate around target structure	The video demonstrates to the participant the importance of recognizing the appropriate spread around the target structure/ nerve.

The total number of errors was noted as well be the number of times an error was repeated during the learning phase.

Twenty-four hours after completion of the Learning Phase, participants attempted the same series of tasks (table 1), on the same phantom model, in the same setting twice in succession; their performances were videotaped according to a standard protocol by a trained investigator (SFS). This was deemed the 24-hour retention test. The instructions were presented to the participants in the form of a printed sheet of paper. The participants did not receive any feedback during the Assessment Phase. Subsequently the videotapes were edited to ensure the participant could not be identified by blinded assessors.

The video recording started as soon as the participant was ready to perform the tasks on the phantom model and ended when the participant had finished performing the tasks.

Two independent experts in regional anaesthesia assessed the videotapes (The experts were defined as having completed a higher specialty training in regional anaesthesia), were unaware of the identity and group allocation of the participant and had undergone instructions and training (two sessions with the principal investigator SFS with training and feedback videos) in identifying the errors.

For the purposes of assessment, the following were defined as errors:

1. Non-orientation of the probe: failure to attempt to orient the ultrasound probe correctly.

2. Incorrect orientation of the probe: failure to orient the ultrasound probe correctly despite attempting to do so.

3. Dominant hand holding the probe while performing task: participant holds the probe in the dominant hand and needle in the non-dominant hand while attempting the tasks.

4. Non-identification of target: the participant does not verbally identify and point to the correct target structure before proceeding with the next task.

5. Depth of target: the participant does not verbally identify the correct depth of the target structure before proceeding to the next task.

6. Participant did not use color-flow analysis to show absence of flow in the target structure: the participant does not apply color-flow analysis correctly to the target before proceeding to the next task.

7. Incorrect holding of the needle: the participant did not hold the needle between the index finger and thumb (as one would hold a pencil) as taught in the training video.

8. Fatigue: the participant changes hands to maintain control of the probe, holds the probe with both hands or demonstrates tremor while holding the probe

9. Non-aspiration before injection: the participant proceeds to injection of fluid around target structure without first aspirating.

10. Identification of inappropriate spread of injectate around target structure: the participant fails to identify inappropriate spread relative to target structure i.e. spread of fluid away from target structure.

11. Target malpositioning on the ultrasound screen: the participant positions the probe such that the target structure is not visible in the centre of the screen.

12. Unintentional probe movement[8]: the participant moves the probe unintentionally i.e. the hand is not stabilized and the target structure changes position on the screen.

13. Insertion of needle in axial plane of ultrasound beam: the participant inserts the needle out of plane to the US beam.

14. Changing the angle of the needle without withdrawing it to place it either above or below the target structure: the participant changes the angle of

the needle without withdrawing the approximately half the length of the needle.

15. Advancement of needle while shaft and tip are not visualized: the participant advances the needle while either tip , shaft or both are not visible onscreen

16. The number of needle passes: the initial needle insertion counts as the first-pass. Any subsequent needle insertion is counted as an additional pass

The total number of errors was noted as well be the number of times an individual error was repeated, independently by the two-blinded assessors.

7.3 Statistical analysis

SPSS version 18 software (SPSS, Inc., Chicago, IL, USA) was used for data analysis. The demographic data was analyzed using Kruskal-Wallis tests and Chi-squared tests. The LP data were summarized for each trial and between group comparisons carried out. The 24-hour retention test data were summarized (using the final performance of LP and that acquired 24 hours later). Normal data were analyzed using ANOVA followed by t-tests adjusted for multiple testing; non-normal data were analyzed using Kruskal-Wallis tests followed by Mann-Whitney U tests. The LP data was also analyzed using repeated measures over time and between groups. Intra-class correlations (ICCs) between assessors were calculated using Cronbach's α for the 24-hour retention test. Bonferroni correction to the p-value was used for multiple testing.

7.4 Results

Subject characteristics are summarized in Table 3. Thirty subjects participated in total, 10 in each group. The three treatment groups were control – no feedback (Control - C), KR and KP feedback. The distribution of age had a positive skew. The median ages in the three groups were similar (Kruskal-Wallis test p=0.485; Table 3). There were 9 females and 21 males – their distributions in the three groups were similar (p=0.240, Chi-squared test; Table 3). Graduate entry versus direct entry, educational qualification, dominant hand, visual acuity, experience of playing video games (including current usage and maximum usage), interval to most recent observation of applied ultrasound and total duration of LP were also similar in the three groups (Table 3).

The learning phase data were summarized for each trial and tested between treatment groups. Each of the parameters measured (imaging time, needling time, performance time, total number of errors and additional needle passes) were similar across the three groups.

For trial 2 the median number of errors was significantly less in group KP (The median for group C: 3.5; group KR: 3.5 and group KP: 1.0; Kruskal-Wallis test – p=0.002). . The median number of additional needle passes was also less in group KP (The median for group C: 2.0, group KR: 1.5, group KP: 0.0; Kruskal-Wallis, p=0.039).

For trial 3 the median number of errors was significantly different between groups (the median for group C: 2.5; group KR: 3.0, group KP: 1.5, Kruskal-Wallis test – p=0.03). The median additional needle passes was also significantly different between groups (The median for group C: 1.5, group KR, 1.0, group KP, 0.0, Kruskal-Wallis, p=0.002). .

For trial 4 the median imaging time was significantly different between groups. (The median for group C: 70.0, group KR: 42.0, group KP: 46.5, Kruskal-Wallis test – p=0.002.) The median number of errors was significantly different between groups (the median for group C: 4.0, group KR: 3.0 group KP: 0.5, Kruskal-Wallis test – p<0.001). The median additional needle passes was significantly different between groups (the median for group C: 1.0, group KR: 1.0, group KP: 0.0, Kruskal-Wallis, p=0.009). .

For trial 5 the median imaging time was significantly different between groups (The median for group C: 58.0, group KR: 35.0, group KP: 45.0, Kruskal-Wallis test – p=0.014). The median number of errors was significantly different between groups (The median for group C: 4.0, group KR: 4.0, group KP: 0.0, Kruskal-Wallis test – p=0.005). . The median additional needle passes was also significantly different between groups (The median for group C: 2.0, group KR: 2.0, group KP: 0.0, Kruskal-Wallis, p=0.009). .

Plots were also constructed showing the trends in each group over the 5 trials for each measure (Figures 1 – 4).

The measurement data were also analyzed using repeated measures over time and between groups. The imaging time means were significantly different over the 5 trials but not between treatment groups. The needling time means were significantly different over the 5 trials but not between treatment groups. The imaging time means were significantly different over the 5 trials but not between treatment groups. The performance time means were significantly different over the 5 trials but not between treatment groups.

The total error means were significantly different over the 5 trials and also between treatment groups. After Bonferroni correction the mean for group C (3.46) was significantly different from the mean for group KP (1.3), $p<0.001$. Also the mean for group KR (3.14) was significantly different from the mean for group KP. $P=0.001$.

The additional needle pass means were significantly different over the 5 trials and also between treatment groups. After Bonferroni correction the mean for group KR (2.22) was significantly different from the mean for group KP (0.3). $P=0.013$.

For the assessment phase data the intra-class correlations (ICC) between assessors was calculated for the scores and was 0.753 (95%CI 0.725, 0.779), which was reasonably high.

The change from trial 5 to assessment time for all measures was then calculated with positive values meaning an increase and negative values meaning a decrease.

For the change in imaging time the mean difference was not significant between groups but it was very close (p=0.09). In fact the mean difference for group C was -2.5, for group KR it was +26.83 and for group KP it was +32.2. Therefore the time reduced for the control group but increased for the other 2 groups.

For the change in needling time the mean difference was not significant between groups (p=0.192).

For the change in performance time the mean difference was just significant between groups (p=0.046). In fact the mean difference for group C was -22.61, for group KR it was +26.56 and for group KP it was +70.65. Therefore the time reduced for the control group but increased for the other 2 groups. When these were tested using t-tests adjusted for multiple testing using Bonferroni adjustment then only the difference between groups C & KP was significant (p=0.042).

For the change in number of errors the mean difference was significant between groups (p=0.01). In fact the mean difference for group C was -1.39, for group KR it was -0.85 and for group KP it was +1.2. Therefore the number of errors reduced on average for the control group and group KR but increased for group KP. When these were tested using t-tests adjusted for multiple testing using

Bonferroni adjustment then the difference between groups C & KP was significant (p=0.014) and also the difference between groups KR & KP was almost significant (p=0.055).

For the change in number of additional needle passes the median difference was significant between groups (p=0.032) (data was positively skewed). In fact the median difference for group C was +0.375, for group KR it was -0.5 and for group KP it was +1.375. Therefore the number of additional needle passes reduced on average for group KR but increased for groups C & KP. When these were tested using Mann-Whitney U tests then the difference between groups C & KP was significant (p=0.027) and also the difference between groups KR & KP was significant (p=0.023).

For the change in number of total errors and additional needle passes the mean difference was significant between groups (p=0.017). In fact the mean difference for group C was -1.84, for group KR it was -0.5 and for group KP it was +2.8. Therefore the number of total errors reduced on average for the control group and group KR but increased for group KP. When these were tested using t-tests adjusted for multiple testing using Bonferroni adjustment then the difference between groups C & KP was significant (p=0.02) and also the difference between groups KR & KP was almost significant (p=0.104).

Finally all average measurements from the assessment phase were tested between treatment groups. None of these were found to be significantly different.

The measurement data were also analyzed using repeated measures between times 1 and 5 only and between groups. The imaging time means were significantly different between these times (p<0.001) but not between treatment groups.

The needling time means were significantly different between trials 1 and 5 (p<0.001) but not between groups.

The performance time means were significantly different between trials 1 and 5 but not between groups.

The total error means were significantly different between trials 1 and 5 (p=0.002) and also between groups (p=0.005). After Bonferroni correction the mean difference between groups C and KP was 1.9 (p=0.007) and the mean difference between groups KR and KP was 1.65 (p=0.022) – the mean difference between groups C and KR was 0.25, which was not significant (p=1.00).

The additional needle pass means were not significantly between trials 1 & 5 (p=0.191) but the differences were significantly different between treatment groups (p=0.042). After Bonferroni correction the mean differences were no longer significant between groups.

Table 3: Participant characteristics			
	Control (n=10)	KR (n=10)	KP (n=10)
Age (Years)	21 (20-41)	23 (22-32)	24 (22-35)
Gender (M: F)	6: 4	6: 4	9: 1
Handedness (R:L:A)	7: 1: 2	10: 0	9: 1: 0
Eye Sight (N:NS:FS)	6: 4: 0	3: 6: 1	5: 4: 1
Video Games	6: 4	6: 4	7: 3

Table 3: Age is presented in Median and Range; gender is presented as Male: Female; Handedness is presented as Right handed: Left handed: Ambidextrous (as declared by participant); Eyesight is presented as Normal: Nearsighted: Farsighted; Video games as Yes: No.

Figure 1: Imaging time: Box-Whisker plots of the Trials 1 – 5 and at 24 hour interval with time in seconds. The middle bar in the box is the mean, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value. Significant differences in-between groups are presented by *.

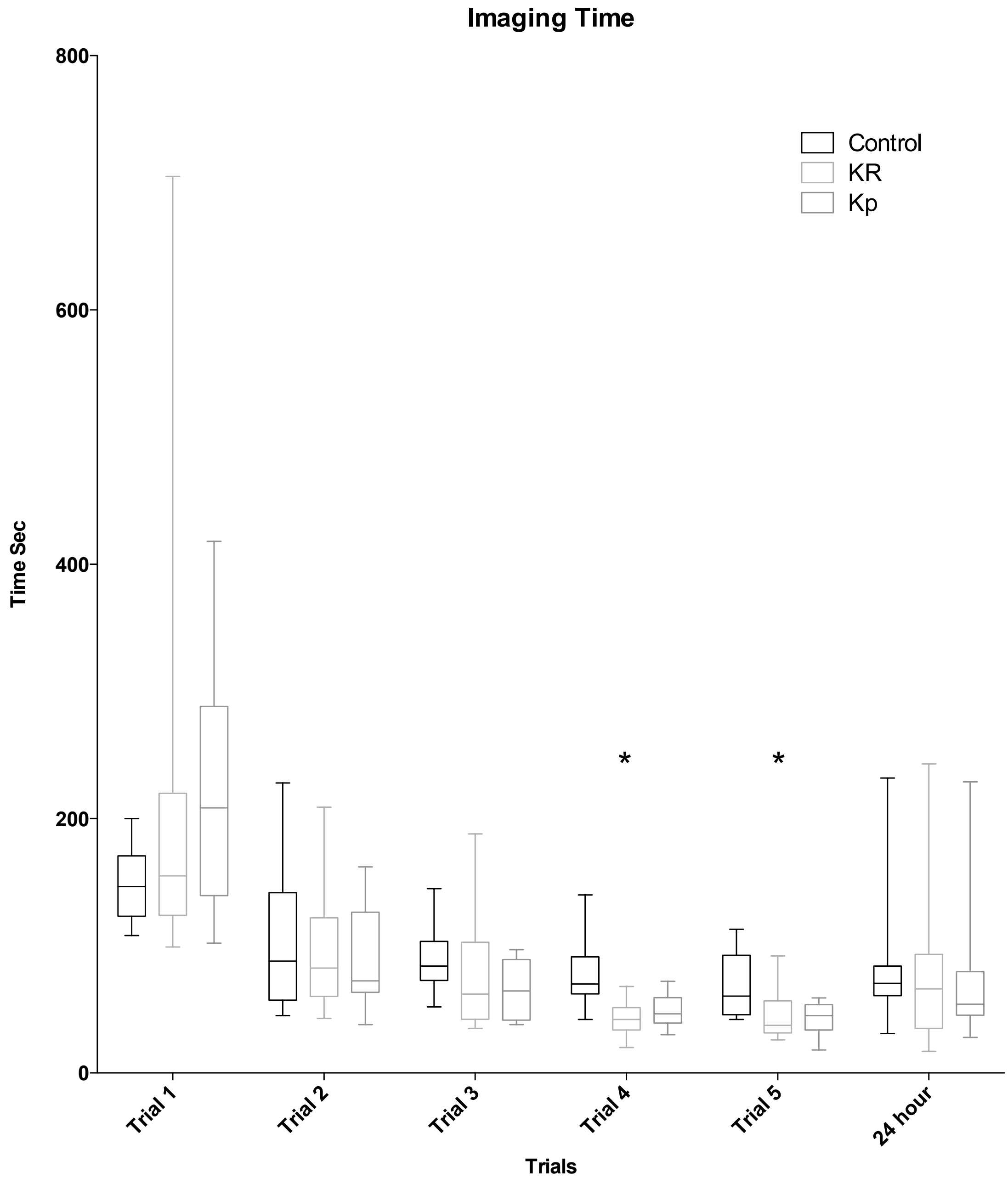


Figure 2: Needling Time: Box-Whisker plots of the Trials 1 – 5 and at 24 hour interval with time in seconds. The middle bar in the box is the mean, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value. Significant differences in-between groups are presented by *.

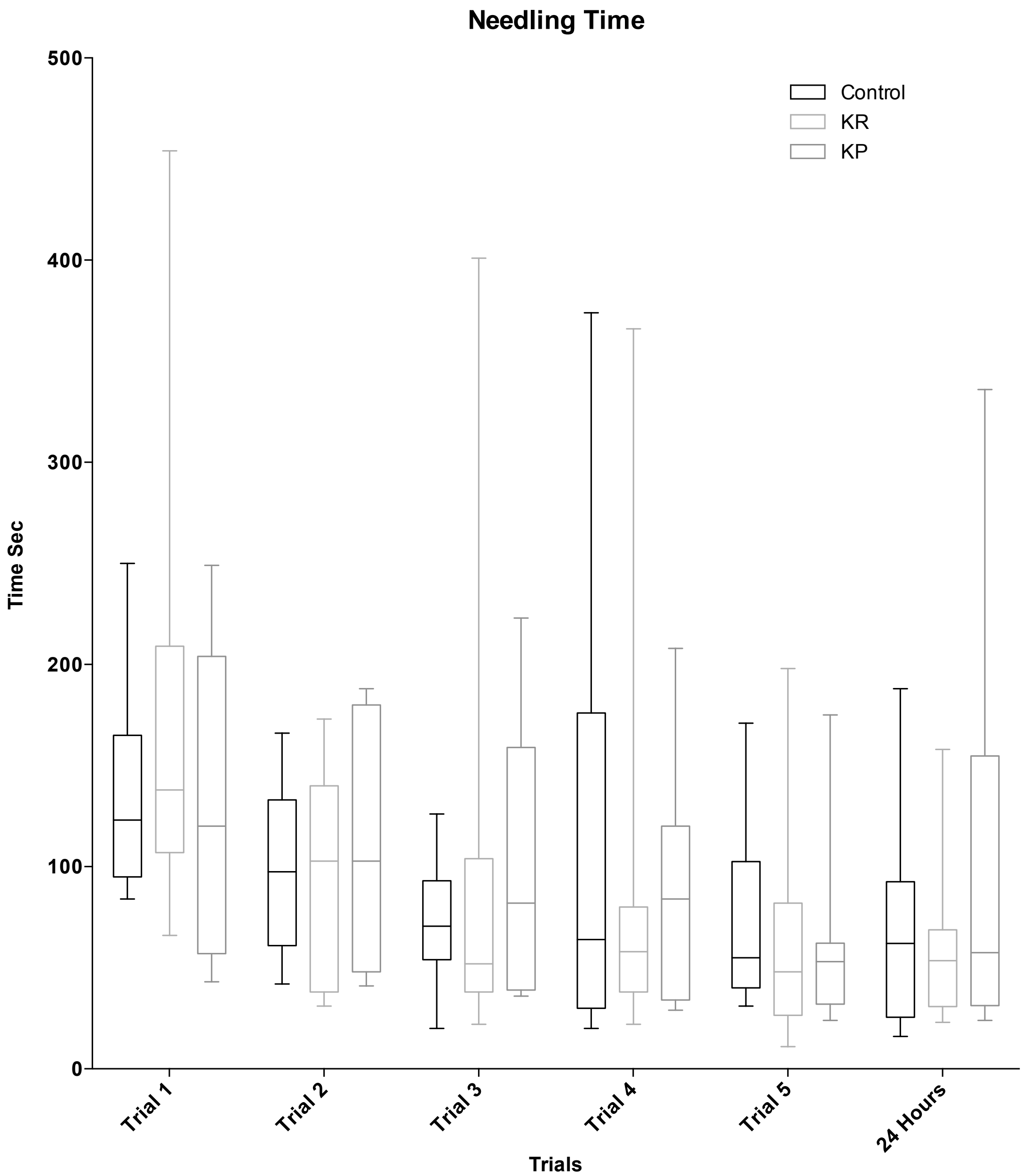


Figure 3: Performance Time: Box-Whisker plots of the Trials 1 – 5 and at 24 hour interval with time in seconds. The middle bar in the box is the mean, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value. Significant differences in-between groups are presented by *.

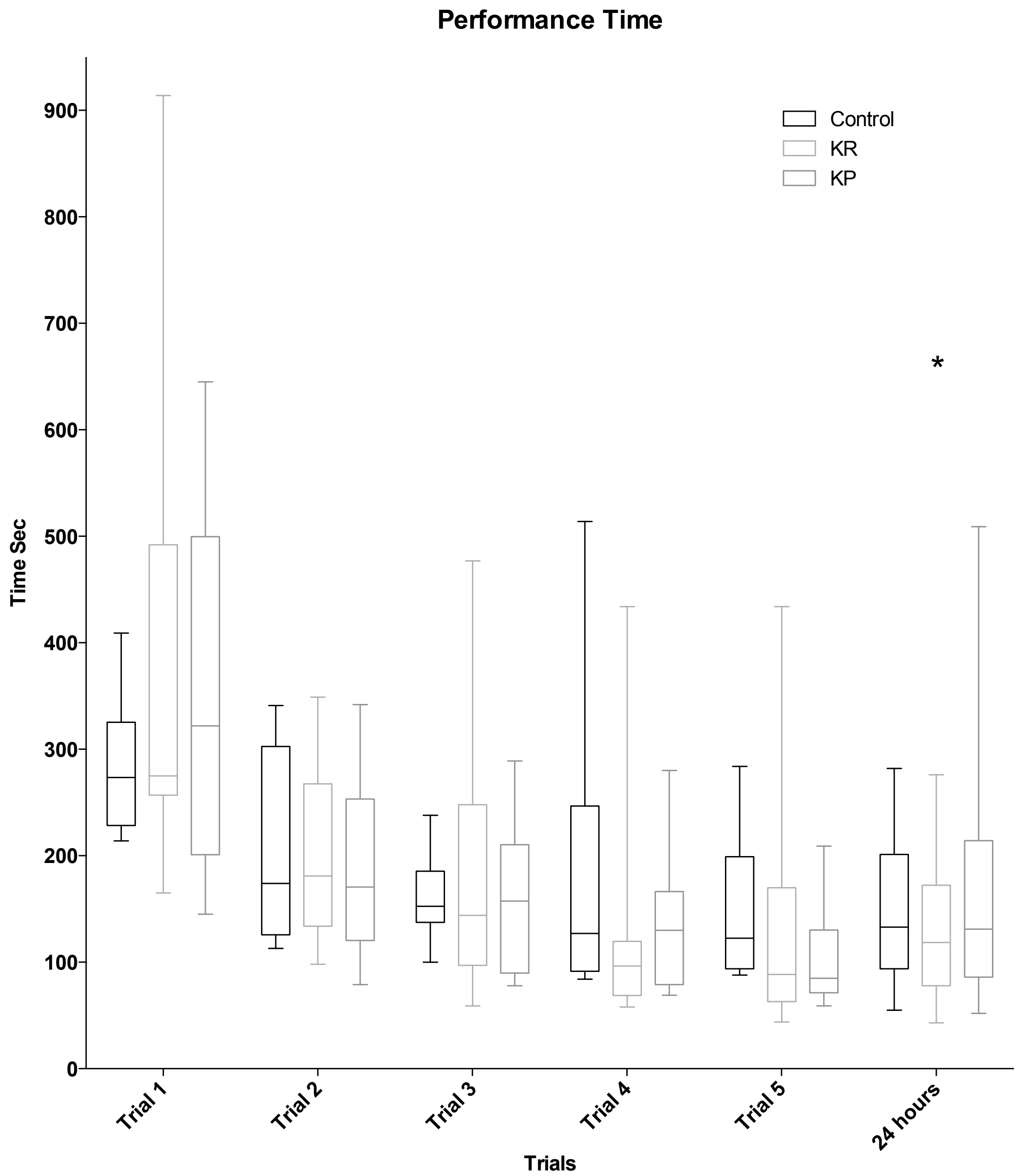
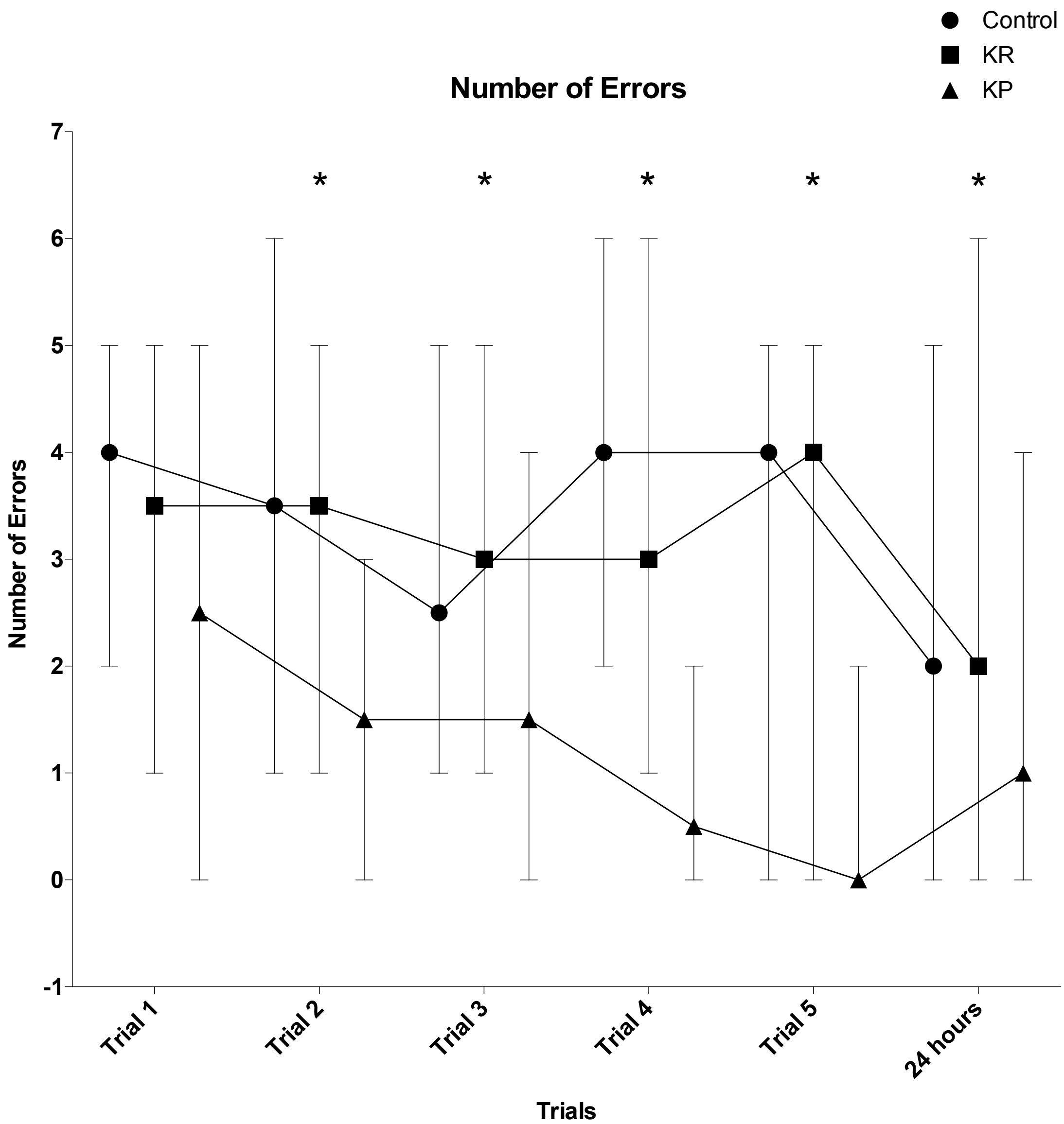


Figure 4: Error Count: Line Plot with Median and Range for the error counts over Trial 1 – 5 and at 24 hour interval. The middle bar in the box is the median, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value. Significant differences in-between groups are presented by *.



7.5 Discussion:

Learning effect was defined as change (decrease) from first to fifth attempt in the intervals measured and in the cumulative error total identified during performance of each set of five tasks.

All groups demonstrated significant learning effect in terms of imaging, needling and performance time intervals. Error reduction was significant over time intervals measured and also in-between groups with significant difference between Control: KP ($p < 0.001$) and KR: KP ($p = 0.001$) but not between control and KR groups.

It was surprising (to the authors) that the time parameters measured did not indicate a difference between the three groups in terms of skill retention, However for the errors there was statistical significance between groups ($p = 0.01$), with fewer errors on average for the control and KR groups and an increase in average errors for the KP group after a time interval of 24 hours.

The most important finding in this study was extent of skill attrition demonstrated (irrespective of the form of feedback) after just 24 hours.

The effect of feedback for skill acquisition is consistent with other studies performed for medical procedures[13 - 14]. The dependency on feedback, by one of the participant in KP group, although unexpected, is well documented. This is described as the “guidance hypothesis” which suggests that augmented feedback during training improves performance but subsequent retention tests may result in performance deterioration and dependancy[15-16].

The study design employed adhered to the principles established for investigation of the effects of feedback on learning[17]. All aspects of the learning and assessment phase were standardized; this included the environment, the participant, the teaching video, the tasks, the phantom model and the feedback.

The phantom models that were used were gelatin based. The gelatin gives a uniform appearance on the ultrasound image; hence the target was the only echogenic structure to identify in the model. All the models were identically reproducible and each participant performed on the same models with the same targets in both the LP and the 24-hour interval. As yet no publication has deemed a gelatin model to be identically reproducible and injectable, at the same time.

All participants were absolute novices to the procedure and had not performed ultrasound-guided procedures previously. All of the participants had volunteered for the study (incentive).

There were a few limitations of the study. Firstly, this study was performed on a bench model; this raises the question of transferability to clinical practice. Secondly, all the participants were medical students, although volunteers, the question of incentive and interest may be raised. Thirdly, we provided feedback for seven of the errors performed only; these errors were all qualitative errors and have been identified as being the most frequently occurring in novices learning in-plane needle manipulation using ultrasound.[8]

7.6 Conclusion

In conclusion, feedback based on knowledge of performance is associated with an increase in the speed of skill acquisition and a decrease in error rate during initial learning. Feedback based on knowledge of results was associated with a greater decrease in time needed for skill acquisition but not a lesser error rate during learning. Interestingly, the content of feedback provided (at least in the setting outlined for this study) was an important determinant of early (24 hour after initial learning) skill attrition. This could have important implications for the design of the many intensive introductory courses for medical procedural skills currently available. The skill attrition after these intensive courses could be very high and the course designers should have means to measure the skill acquisition as well as skill attrition.

Future research may be directed towards identifying factors that may hasten skill acquisition, prolong skill retention or alternatively delay skill attrition.

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8 A comparison of immediate, learner-led versus terminal feedback on skill acquisition for ultrasound-guided needle manipulation in a simulated setting.

8.1 Introduction

Feedback refers to “specific information one receives about one’s performance that is intended to improve future performance”[1,2]. It is a cornerstone of effective teaching and an important determinant of motor learning[1]. Feedback has been identified as the most important determinant of effective learning in a simulated setting[2]. In order to optimize learning, feedback must be delivered in an appropriate manner[3]. When feedback is provided during the performance of a skill it is referred to as immediate or concurrent feedback; when provided on completion of a skill it is referred to as delayed or summary feedback[4]. The timing of the feedback has been shown to influence motor learning for discrete tasks such as suturing.[4] The utility of delayed feedback in a clinical setting is obviously limited out of concern for patient safety. During simulation-based training, a performance can progress despite errors enabling trainees’ additional opportunities to identify and learn from mistakes[3]. Schmidt and Bjork have postulated that performance improves equally with concurrent or summary feedback, but that summary feedback results in superior learning when evaluated after a rest period with no feedback[5].

Objective

The principal objective of this study was to determine the effect, if any, of timing and nature of feedback to novices on skill acquisition for needle manipulation using ultrasound guidance by novices in a simulated environment.

8.2 Methods

In a previous study, the methodology described below has been used by these investigators to study other aspects of feedback in a different cohort of learners (Chapter number 7).

A letter of invitation to participate was sent to all 3rd and 4th year medical students of University College Cork (UCC) Ireland. Previous training or experience of performing ultrasound-guided procedures was an exclusion criterion. With institutional Ethical approval and having obtained written informed consent from each, twenty-four 3rd and 4th year medical students participated.

For each participant, the following baseline data were collected: age, gender, visual acuity, dominant hand, videogame use and greatest educational qualification. Each participant then viewed a video tutorial on ultrasound and the procedure to be performed.

Tutorial Video Development.

The video tutorial specified the five tasks that each participant was asked to perform. (Table 1) The video script was drafted and revised in consultation with members of the Medical Education Unit at UCC who have expertise in the assessment of medical competences and in technology enhanced learning for health professionals.

The script was enacted and video recorded using Sony HX5V HD (Sony DSC-HX5V HD, SONY Corp, China) and using standardized shot framing and event capture. A concurrent real time recording was made of the ultrasound images using K-World Video Editing DVD Maker 2 (KWorld Computer Co., Ltd., Jhonghe City, Taipei County, Taiwan). The videotapes were edited (iMovies '09 version 8.0.6, video editing software, Apple Inc 2010, Mac OS X Version 10.7.2, US) to present the procedure on one screen using picture-in-picture, with the ultrasound image on the left bottom corner of the screen and synchronized with procedure images. The duration of the final tutorial video was eight minutes.

The tutorial video was independently evaluated by five consultants with extensive and current experience in medical student teaching and independently by five other consultants with expertise in regional anaesthesia for content validity. It specified the five tasks that each participant was asked to perform (Table 1). The tutorial was delivered individually to each participant in a standardized environment using Philips SHB6110 wireless-blue-tooth headphones (Koninklijke Philips Electronics N.V). The Netherlands. www.philips.com). The standardized environment was set up adjacent to the operating theatre block at Cork University Hospital, Wilton, Ireland. The configuration and the equipment used were identical for the duration of the study. The ultrasound machine (M-Turbo Ultrasound System, SonoSite Inc, Bothell, WA 98021, USA with a linear probe 6 – 13 MHz) and the phantom model were adjacent to one another on a dedicated trolley.

Phantom Model Development:

The phantom used was a gelatin-based model. All models had standardized dimensions, 3.5 cm deep with target structures embedded between 0.5 – 1.5 cm. The target structure was a bean pod (magnetout bean). The ultrasonographic appearance of the bean in the pod bears some resemblance to a nerve/ nerve root and penetration of the wall of the bean pod evoke the sensation of needle penetration of a fascial plane; the sonographic appearance of the bean pod wall bears some resemblance to that of a fascial plane. The bean pods were prefilled with 0.9% normal saline (1 mL) to create a space into which the needle tip could be advanced and were further expansible on injection. All of the models were opaque, such that the target structures were not visible to the naked eye. The gelatin phantom was placed on a "light box". When switched on, transillumination enabled the participant to see the target (bean pod) and assess the degree of alignment of the axes of needle and ultrasound probe and the position of the needle relative to the target. The light box was switched on and off by an investigator, at the request of the participant. The number of times the light box was switched on was recorded.

Participants were randomly allocated to one of two groups:

i. Immediate/ Concurrent Feedback (I): participants were given augmented visual error correction feedback on demand. The participants controlled the timing and frequency of feedback themselves by requesting it.

ii. Delayed/ Summary Feedback (D): participants were given feedback in the form of identification and correction advice based on the errors made, at the end of each series of tasks.

The sets of feedback were standardized using video formatting. Development of the predefined errors and standardized advice entailed a similar process to that described above for the training video.

Table 1: Tasks and Task Definitions		
Task 1	Orientation of the probe	To apply ultrasound gel to the probe and the probe to the model. To verify, verbally, which side of the ultrasound probe corresponded to the blue dot on the ultrasound screen. To confirm that the right side of the screen represented the phantom structures on the participant's right side
Task 2	Identification and depth measurement of the target structure in the phantom model.	To scan the model using the ultrasound probe; to identify the target structure in the model in a cross-section view; to verbally confirm the location and depth of the target structure with the investigator
Task 3	Use of color-flow analysis to rule out the possibility that the structure was not identified as a blood vessel	To verify that the target structure was not a blood vessel, by using the color-flow function appropriately
Task 4	Insertion of the needle using the in-plane technique towards the target structure,	To insert the needle using in-plane technique and to advance it towards the target structure, keeping the shaft and tip of the needle in view throughout. To

	maintaining the shaft and tip of the needle in view at all times	position the needle tip above the target structure
Task 5	Aspiration and injection of fluid around the target structure under US guidance, keeping the needle tip in view at all times	To aspirate and then inject keeping the needle positioned immediately above the target structure. To demonstrate the spread of injectate around the target structure using real time US

This was deemed the Learning Phase (LP) and had a maximum duration of 60 minutes.

All participants had access to the video tutorial and the training material (phantom, needle, assistant). This is referred to as the Learning Phase (LP). During the LP, the participants were instructed to attempt each set of tasks five times, during which they attempted to achieve three learning outcomes, namely:

iv. Minimize imaging time: defined as the interval between contact of the ultrasound probe with the model and the acquisition of a satisfactory image.

v. Minimize needling time: defined as the interval between the initial needle insertion and withdrawal of needle from the model.

vi. Minimize performance time: defined as the sum of imaging and needling times.

Standardized advice was developed for certain of the pre-defined errors (those for which the means of correction were not immediately obvious) Table 2.

Table 2: Error and Advice	
Non-orientation of the probe	The video demonstrates to the participant the importance of orientation of the probe and how to perform it.
Incorrect orientation of the probe	The video demonstrates to the participant to turn the US probe 180 degrees or to insert needle on the opposite side of US probe with respect to original insertion site.
Needle advanced while not visualized in the longitudinal plane of the ultrasound image.	The video demonstrates to the participant how to insert the needle in the longitudinal plane; and explains the risks of advancing a needle without visualizing both shaft and tip. The video also demonstrates how to move or angle the US probe to search for the needle.
Insertion of the needle in the axial plane of the ultrasound beam.	The video demonstrates that a 22- gauge needle visualized on axial section appears as small dot that is difficult to analyze for anatomic location the correct performance was also shown.
Failure to recognize the needle had contacted the endpoint	The video demonstrates to the participant that he or she has to watch the ultrasound image as the needle approached the target.
Failure to aspirate before	The video demonstrates to the participant the

injection	importance of aspiration, to verify whether the needle tip is intravascular or not.
Failure to recognize inappropriate spread of injectate around target structure	The video demonstrates to the participant the importance of recognizing the appropriate spread around the target structure/ nerve.

For each participant's LP, the total number of errors was recorded as well be the number of times an individual error was repeated.

Twenty-four hours after completion of the LP, participants attempted the same series of tasks (Table 1), on the same phantom model, in the same setting twice in succession; their performances were videotaped according to a standard protocol by a trained investigator. This was referred to as the 24-hour skill retention test. The instructions were presented to the participants in the form of a printed sheet of paper. The participants did not receive any feedback during the 24-hour skill retention test. Subsequently the videotapes were edited to ensure the participant could not be identified by blinded assessors.

The video recording started as soon as the participant was ready to perform the tasks on the phantom model and ended when the participant had finished performing the tasks.

Two independent experts in regional anaesthesia assessed the videotapes An expert was defined as an anaesthetist who had completed formal higher sub-specialty training in regional anaesthesia and whose current practice included a substantial component of US-guided peripheral nerve blockade. The experts were unaware of the identity and group allocation of the participant, and had each undergone instructions and training (two sessions with the principal investigator SFS with training and feedback videos) in identifying the pre-defined errors.

For the purposes of assessment, the following were defined as errors:

17. Non-orientation of the probe: failure to attempt to orient the ultrasound probe correctly.

18. Incorrect orientation of the probe: failure to orient the ultrasound probe correctly despite attempting to do so.

19. Dominant hand holding the probe while performing task: participant holds the probe in the dominant hand and needle in the non-dominant hand while attempting the tasks.

20. Identification of target: the participant does not verbally identify and point to the correct target structure before proceeding with the next task.

21. Depth of target: the participant does not verbally identify the correct depth of the target structure before proceeding to the next task.

22. Color-flow analysis to show absence of flow in the target structure: the participant does not apply color-flow analysis correctly to the target before proceeding to the next task.

23. Hand position on the needle: the participant did not hold the needle between the index finger and thumb (as one would hold a pencil) as taught in the training video.

24. Fatigue: the participant changes hands to maintain control of the probe, holds the probe with both hands or demonstrates tremor while holding the probe

25. Aspiration before injection: the participant proceeds to injection of fluid around target structure without first aspirating.

26. Appropriate spread of injectate around target structure: the participant fails to identify inappropriate spread relative to target structure i.e. spread of fluid away from target structure.

27. Target malpositioning on the ultrasound screen: the participant positions the probe such that the target structure is not visible in the centre of the screen.

28. Unintentional probe movement: the participant moves the probe unintentionally i.e. the hand is not stabilized and the target structure changes position on the screen.

29. Insertion of needle in axial plane of ultrasound beam: the participant inserts the needle out of plane to the US beam.

30. Changing the angle of the needle without withdrawing it to place it either above or below the target structure: the participant changes the angle of the needle without withdrawing the approximately half the length of the needle.

31. Advancement of needle while shaft and tip are not visualized: the participant advances the needle while either tip, shaft or both are not visible onscreen

32. The number of needle passes: the initial needle insertion counts as the first-pass. Any subsequent needle insertion is counted as an additional pass

The total number of errors and the number of times an individual error was repeated, were noted independently by the expert assessors.

8.3 Statistical Analysis

SPSS version 18 software (SPSS, Inc., Chicago, IL, USA) was used for data analysis. The demographic data were analyzed using Kruskal-Wallis tests and Chi-squared tests. The LP performance data were summarized for each trial; LP data were analyzed using repeated measures over time (attempt 5 vs attempt 1) and between groups. . The 24-hour skill retention test data were summarized for the two performances by each participant. Normally distributed data were analyzed using ANOVA followed by t-tests adjusted for multiple testing (Bonferroni correction) ; non-normal data was analyzed using Kruskal-Wallis tests followed by Mann-Whitney U tests. Intra-class correlations (ICCs) between assessors were calculated using Cronbach's α for the 24-hour retention test.

8.4 Results

Twenty-four participants were recruited for the study. All participants completed the LP and performed five sets of tasks five times. Twenty-three participants performed the same five sets of tasks twice in succession during the 24-hour skill retention test. One participant (Group D) expressed insufficient confidence to perform the tasks without first reviewing the training video and did not participate in the 24 hr skill retention test.

The two groups were similar in terms of baseline characteristics. Although the distribution of age had a positive skew, the median age in the two groups was similar p=0.63. There were more males than females in group I.

The two groups were similar in terms of the parameters measured in trials 1-5 (namely imaging time, needling time, performance time and total number of errors. Imaging times, needling times, and performance times (means) were each significantly different (progressively shorter) over the 5 trials but not between the two groups (Figures 1-3). The total numbers of error (means) were significantly different (progressively fewer) over the 5 trials (p=0.005) but not between groups (Fig 4).

The intra-class correlations (ICC) between assessors was 0.765 (95% CI 0.734, 0.792).

Learning effect was defined as change (decrease) from first to fifth attempt in the intervals measured and in the cumulative error total identified during performance of each set of five tasks.

For each parameter, the difference between trial 5 to 24-hour retention test for all measures was also calculated (positive values meaning an increase and negative values meaning a decrease) and taken to be a measure of skill retention.

Imaging times for both groups were greater during the 24 hr skill retention test that during the fifth attempt of the LP (median differences 21.25 and 12.75s for I and D groups respectively). The difference between groups was not statistically significant (p=0.78).

The two groups were similar in terms of the differences in needling time, performance time and total number of errors (fifth attempt of LP vs 24 hr retention test) (p=0.55, p=0.84 and p=0.98 respectively).

The number of feedback requests by those in-group I during the learning phase are summarized in Table 3.

Table 3: Feedback Provided to Participants		
	Immediate (n=12)	Delayed (n=12)
Total Errors	45	48
Total Feedback	8	48

Total Errors refers to the total number of errors performed by each group during learning phase; Total feedback refers to the number of feedback provided to participants as per protocol.

Figure 1: Imaging time: Box-Whisker plots of the Trials 1 – 5 and at 24-hour interval with time in seconds. The middle bar in the box is the mean, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value.

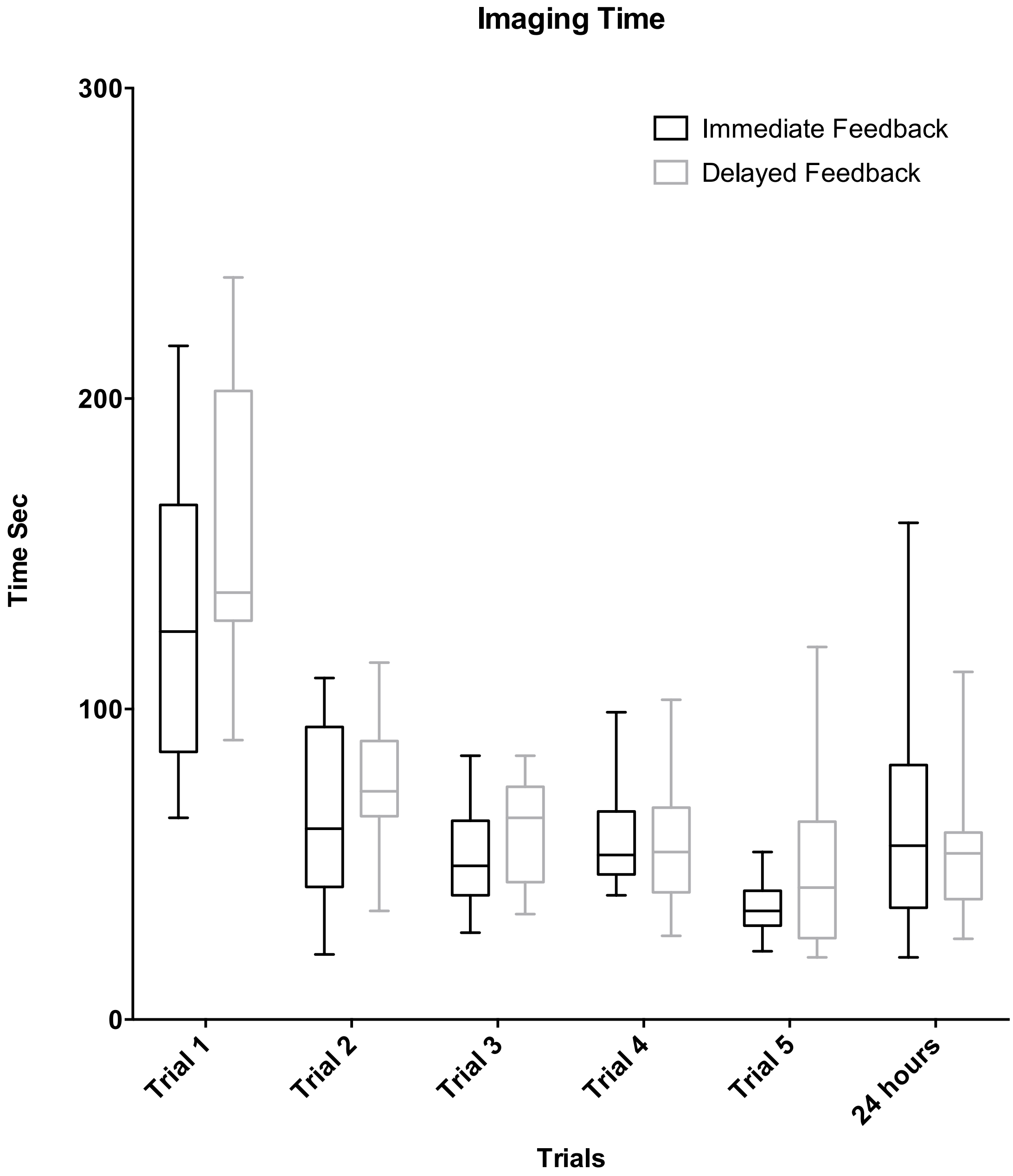


Figure 2: Needling Time: Box-Whisker plots of the Trials 1 – 5 and at 24-hour interval with time in seconds. The middle bar in the box is the mean, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value.

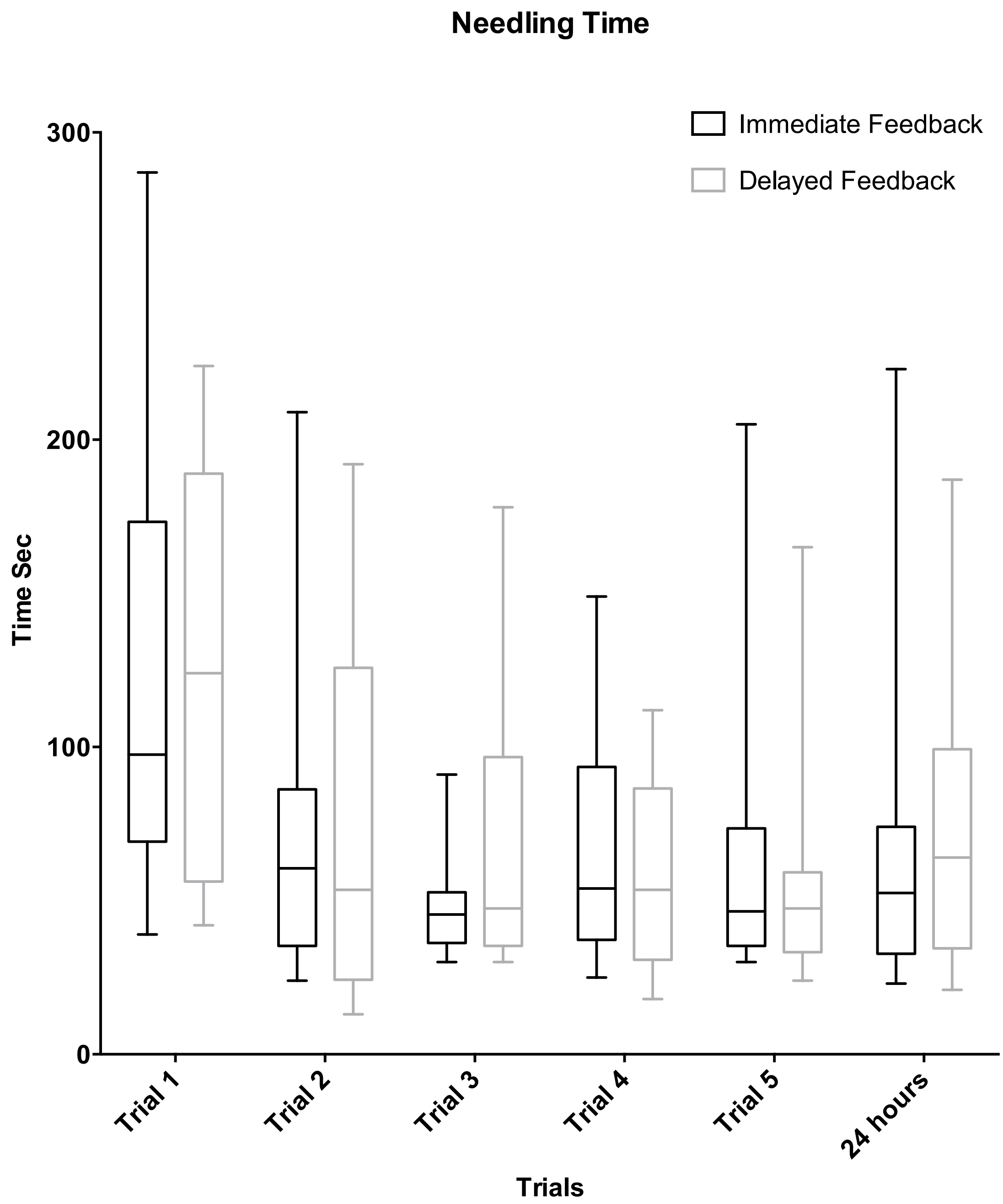


Figure 3: Performance Time: Box-Whisker plots of the Trials 1 – 5 and at 24-hour interval with time in seconds. The middle bar in the box is the mean, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value.

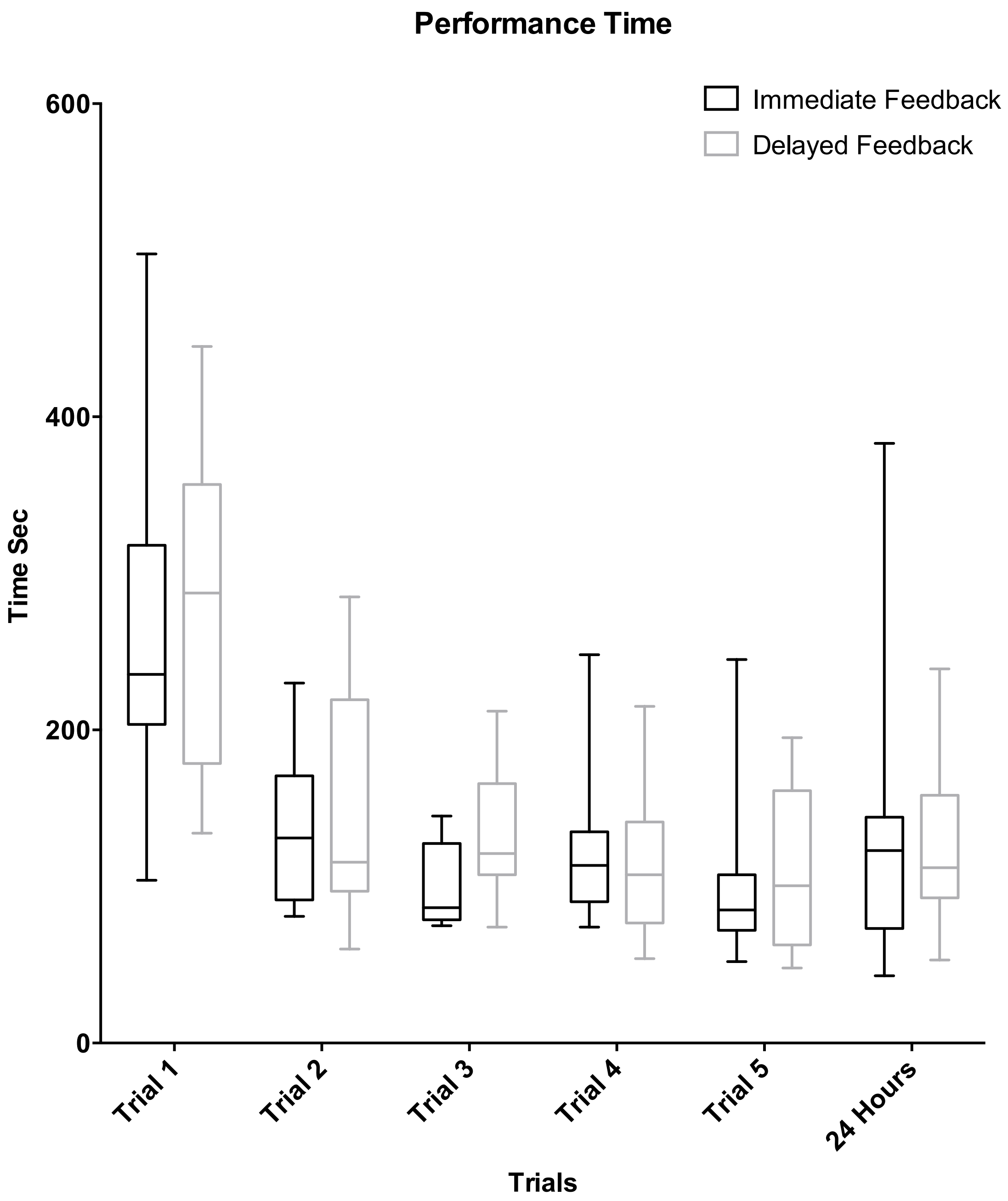
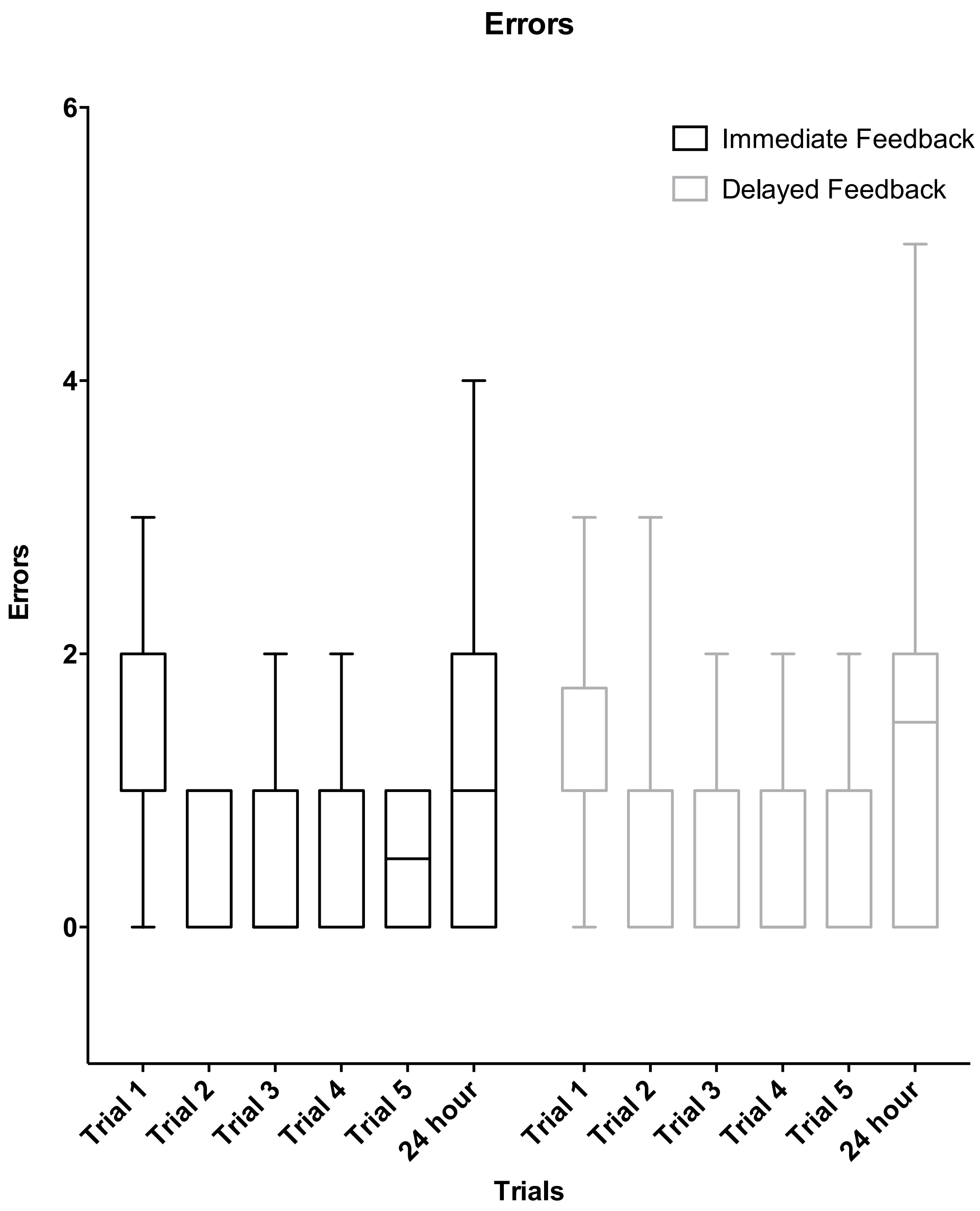


Figure 4: Error Count: Line Plot with Median and Range for the error counts over Trial 1 – 5 and at 24 hour interval. The middle bar in the box is the median, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value.



8.5 Discussion

The most important findings of this study were: i. the lesser amount of feedback required by participants in Group I (immediate feedback) to achieve the same degree of learning (error and performance time reduction) as equivalent participants in Group D (delayed feedback) with a statistically significant and similar reduction in errors performed in LP and ii. the marked skill attrition (measured by errors count and imaging times) in both groups within 24 hrs of intensive and effective learning.

The effect of feedback for skill acquisition we have demonstrated is consistent with that of other studies performed for medical procedures[6,7]. The dependence on feedback, by one of the participant in-group D, is well documented. Referred to as the “guidance hypothesis”, it is proposed that augmented feedback during training improves performance but subsequent testing may demonstrate performance deterioration and dependence on readily available feedback[8,9].

The study conforms to the design recommended for investigation of the effects of feedback[10]. All aspects of the LP and 24 hr retention testing were strictly standardized, (including the environment, the teaching video, the tasks, the phantom model and the manner in which feedback was provided); this was intended to limit the influence of confounding.

The gelatin-based phantom models that were used were specifically designed to facilitate this study. The gelatin gives a uniform appearance on the ultrasound image; hence the target was the only echogenic structure to identify in the model. All the models were reproducible and each participant performed on the same models with the same targets in both the LP and during the 24 hr retention test.

The equivalence of the two groups for baseline characteristics and the exclusion of those with prior experience of US –guided medical procedures ensures a uniform cohort of participants. One might assume that as each participant volunteered to participate, that they shared a reasonably equivalent level of motivation

This study has several limitations. Firstly, it was performed using a bench model, which may limit its direct relevance to learning in a clinical setting. Secondly, all the participants were medical students; this particular skill is most often acquired during postgraduate training one might question the external validity to other cohorts of learners. Thirdly, we provided feedback for only seven of the many (theoretically infinite number of) errors, which could have occurred. These errors (all qualitative) were selected based on previous work, which identified them as those most frequently observed in novices learning in-plane needle manipulation using ultrasound[11].

In conclusion, both forms of feedback studied were associated with effective learning of predefined skills. Those provided with of feedback on demand (immediate feedback) achieved similar amounts and rates of learning with fewer feedback "events" than those who received delayed feedback. A marked attrition of skills was demonstrable 24 hrs after they have first been learned; the magnitude of this attrition was similar in both groups. These findings can inform the design of training programmes for US-guided peripheral nerve blockade and perhaps other similar procedures. Further work is required to address the important and under-recognized issue of procedural skill attrition after learning at short intensive training courses, skill retention or delay skill attrition

Future research should be directed towards identifying factors that will hasten and improve skill acquisition, prolong skill retention and delay skill attrition.

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9 Effect of an intense training programme for identification of brachial plexus in the axilla using ultrasound guidance by novices

9.1 Introduction

Ultrasound is being used more commonly to guide peripheral nerve blockade and regional anaesthesia[1, 2,3]. It is used for anatomic evaluations and for performance of both neuraxial and peripheral nerve blocks. According to the recommendations of the Joint Committee of the American Society of Regional Anaesthesia (ASRA) and of the European Society of Regional Anaesthesia and Pain Medicine (ESRA) (Joint Committee) the three most important tasks for performance of USgPNB (ultrasound guided peripheral nerve blockade) are: 1 - visualization of key landmark structures including blood vessels, muscle, fascia and bone. 2 - Identification of nerves or plexus on short axis view. 3 – Confirmation of normal anatomy and recognition of anatomical variation.[4] To attain competency and proficiency in ultrasound guided regional anaesthesia, the Joint Committee categorizes the skill sets as: 1 – Understanding device operation, 2 – Image optimization, 3- Image interpretation and 4 – Visualization of needle insertion and injection of local anaesthetic solution. Image optimization (non-device related) requires that one learns application of pressure, alignment, rotation and tilt of the transducer (PART maneuver). Image interpretation is further categorized as identification of the nerves, muscle and fascia, distinction between artery and veins, identification of bone and pleura, identification of common acoustic artifacts and variations. It is recommended that one practice ultrasound-scanning techniques on one-self and one's colleagues in order to improve the skills of image optimization and image interpretation.[4]

Axillary brachial plexus block is one of the most commonly performed peripheral nerve blocks for upper limb surgery[5]. There is substantial topographic variation of the four nerves in the axilla, the most frequent arrangement occurring in fewer than two-third of the patients[6].

The number of "practice" attempts necessary to attain competency at a particular procedure varies from one practitioner to another (defining competence for this purpose is itself problematic and in practice often ill-defined). Current training programmes extend over a period of weeks to months and are dependent on the availability of patients, trainers and trainees to attain the experience and/or a defined proficiency level. The well-recognized need for training in USgPNB has led to the development of numerous short intensive courses for trainees of different levels of experience and addressing one or more procedures. Practitioners of different levels of experience in anaesthesia attend these training programmes. Our overall goal in this study was to assess the effect of one intensive training program on the acquisition, retention and attrition of a defined set of key procedural skills, namely those necessary for identification of the brachial plexus (and its component parts) in the axilla using ultrasound.

Objective

i To examine skill retention following an intensive training course on identification of the brachial plexus (and its component parts) in the axilla using ultrasound guidance by novices. Secondary objectives were to assess, the influences (if any) of duration of experience in anaesthetic practice of participants on skill acquisition and retention.

9.2 Methodology

All anaesthetists in the Department of Anaesthesia at our institution (65 in total) were invited to participate in the study. Inclusion criteria was that the participant had no formal training in the scout scan for identification of the brachial plexus at the level of the axilla and had performed no ultrasound-guided axillary brachial plexus block (UgABPB) in the previous 5 years.

With Institutional Ethical approval and having obtained a signed informed consent from each, each participant was invited to identify the brachial plexus at the level of the axilla, on a healthy volunteer (one volunteer participated throughout the study period and he also provided written informed consent).

Each training session was supervised by an anaesthetist with expertise in UgABPB and performance of the scout scan; for this purpose expertise was defined as “having completed a higher sub-specialty fellowship level training in peripheral nerve block and whose current practice included substantial component of US-guided peripheral nerve blockade”. The expert used a validated checklist[7], which was expanded using hierarchical task analysis (HTA) of UgABPB to score the scout scan[8]. (Appendix V)

All participants underwent baseline psychometric testing using Purdue Peg Board for gross and fine motor movement and co-ordination; Cube Comparison for spatial orientation; Snowy Picture for speed of closure, ability to identify partially hidden objects; Shape Memory test for memory and visual recognition.[9]

Baseline data collected from each participant comprised gender, age, level of education, level of training (years of experience in anaesthesia) and Psychometric Test score.

Teaching Phase (TP)

At least 48 hours before commencing training participants received reading material that "provides an instructive review of the essential functions universal to modern ultrasound machines in use for regional anaesthesia"[10] and written material that describes the topographic variations in the arrangement of the four main brachial plexus nerves at the junction of the axilla and the upper part of the arm[6].

All participants received a didactic tutorial on scout scanning technique delivered by an expert (definition above). This tutorial was in the form of a presentation and a demonstration of the technique on a volunteer, with a previously defined normal anatomy. The expert used a validated checklist[7], which was expanded using hierarchical task analysis (HTA) of UgABPB to score the scout scan[8]. (Appendix I). This was referred to as Teaching Phase (TP).

The tutorial included the ultrasound scanning technique. The different maneuvers used to optimize the image were described and demonstrated namely the PART-maneuver (Pressure, Alignment, Rotation and Tilt), as were identification of the individual nerve structures, tracking of the nerve structure distally and proximally again along its path and to confirm the anatomy. Each participant was shown the procedure and then provided with an opportunity to carry out the procedure. During TP all participants were allowed to ask questions and observe the procedure more than once.

Learning Phase (LP)

Each participant attempted scout scans under direct supervision, on the same volunteer, until they are able to identify the four nerves of the brachial plexus at the level of the axilla and to follow each nerve distally to the elbow and proximally to the axilla. This process was referred to as the Learning Phase (LP).

The volunteer's arm was placed in a standard position as described by Winnie "The volunteer was placed in supine position with the arm abducted to approximately 90 degrees and the forearm flexed to 90 degrees and externally rotated so that the dorsum of the hand lies on the table and the forearm is parallel to the long axis of the volunteers body"[11]. This position of the arm was maintained throughout the procedure. Ultrasound imaging was performed using a ultrasound machine (M-Turbo Ultrasound System, SonoSite Inc, Bothell, WA 98021, USA) using a linear array probe (8 MHz – 12 MHz).

The probe was oriented in the horizontal plane so that the bicep muscle appeared at the left side of the ultrasound screen and the triceps muscle appeared on the right side of the ultrasound screen. This was standardized for all participants.

Feedback was provided to the participant on demand, by the expert. The LP was completed when each participant had achieved competence in scout scan and successfully performed each item in the checklist, a total of 45 tasks. The total time required by each participant to achieve competence during the LP was recorded. The performance time (duration) of the final attempt during the LP was taken as baseline at end of training for comparison.

Assessment Phase (AP)

After the LP was complete each participant underwent assessment (using the same volunteer subject) after a minimum of 24 hours time interval, at 14 (+/- 2) days and at 30 days later. Each scout scan was supervised by an expert other than he/she who had supervised the participant's LP, who carried out an assessment using the same checklist. During the AP the time taken to perform the procedure and the total checklist score were recorded for each participant.

The participants, as part of study, did not perform any scout scans between the LP and the AP at 24 hours, 14 days and 30 days.

9.3 Statistics

SPSS version 18 software (SPSS, Inc., Chicago, IL, USA) was used for data analysis. All Graphs were made using GraphPad Prism version 6.00 (GraphPad Software, La Jolla California, USA). Performance data were analyzed using non-parametric Kruskal-Wallis test and if significant Dunn's test for pair-wise comparison with LP. Baseline psychometric data, performance times and checklist scores over time were examined for association with the participant's duration of experience of practicing anaesthesia. For parametric data Pearson's and for non-parametric data Spearman's Rho correlation was used to examine these associations. To determine the reliability of assessment provided by the two assessors, intra-class correlation was calculated for the checklist scores using Parsons correlation.

9.4 Results

Sixteen anaesthetists were recruited. One participant withdrew consent, at the 14-day assessment (the participant expressed insufficient confidence in performing the task without reviewing the checklist); all of this participant's data were excluded from analysis at his request. Two participants did not perform on day 14 (unavailable) but completed on day 30.

Seven females and 8 males participated. The age of participants had a positive skew with a median on 30 (IQR 29,43). The number of years of experience practicing in anaesthesia demonstrated positive skew with a median of 12 years (IQR 1,13).

Baseline psychometric tests did not demonstrate a relationship with the years of experience in anaesthesia. Greater Purdue pegboard scores were associated with greater checklist scores at 24 hours $r=0.66$, $p=0.008$.

The checklist scores for procedure over time are summarized in Figure 1.

For the checklist scores the LP score of 45 was used as baseline for all participants. The checklist scores (median and range) for the assessments at 24 hour were 31 (22-41), at 14 days 28 (28-45) and at 30 days 34 (11-37). Pair-wise comparison with LP baseline score (45 achieved by all participants) demonstrated a significant decrease in checklist score ($p< 0.0001$) at each of the three assessments.

Checklist scores at 24 hours demonstrated a negative correlation with years of experience in anaesthesia, a Pearson's correlation coefficient of -0.661, p=0.007 but not at 14 days and 30 days.

Inter-rater reliability for the assessments between the two assessors was high Parsons correlation 0.885 (p=0.001).

The performance time for procedure are summarized in Figure 2.

Total time for TP had a positive skew with a median of 1236, (IQR 974, 1438). There was a weak relationship between this and years of experience in anaesthesia.

Performance time for the TP and LP demonstrated a weak association (not statistically significant) with years of experience in anaesthesia.

The final attempt during the LP was considered as baseline for the purpose of comparison with subsequent performances. The performance times for the three subsequent performances demonstrated a trend towards increase (vs LP final attempt) that did not achieve statistical significance (p = 0.0728).

The mean change in performance time from LP to the AP at 24 hours, 14 days and 30 days for performance time (in sec) were -345, -242 and -354 seconds respectively.

There was no relationship between performance times during the LP and participants' years of experience in anaesthesia.

Performance times for AP at 24 hours, 14 days and 30 days tended to be less as participants' duration of experience in anaesthesia increased; there was no association, $r^2 = 0.098$, 0.073 and 0.001 respectively when examined with years of experience practicing anaesthesia.

Figure 1: Checklist Score over time. The score at end of Learning Phase is 45 for all participants. 24 hours, 14 days and 30 days represent assessment time intervals. The scores are presented as median and range. * represents statistical significance relative to best/final performance during LP p< 0.0001.

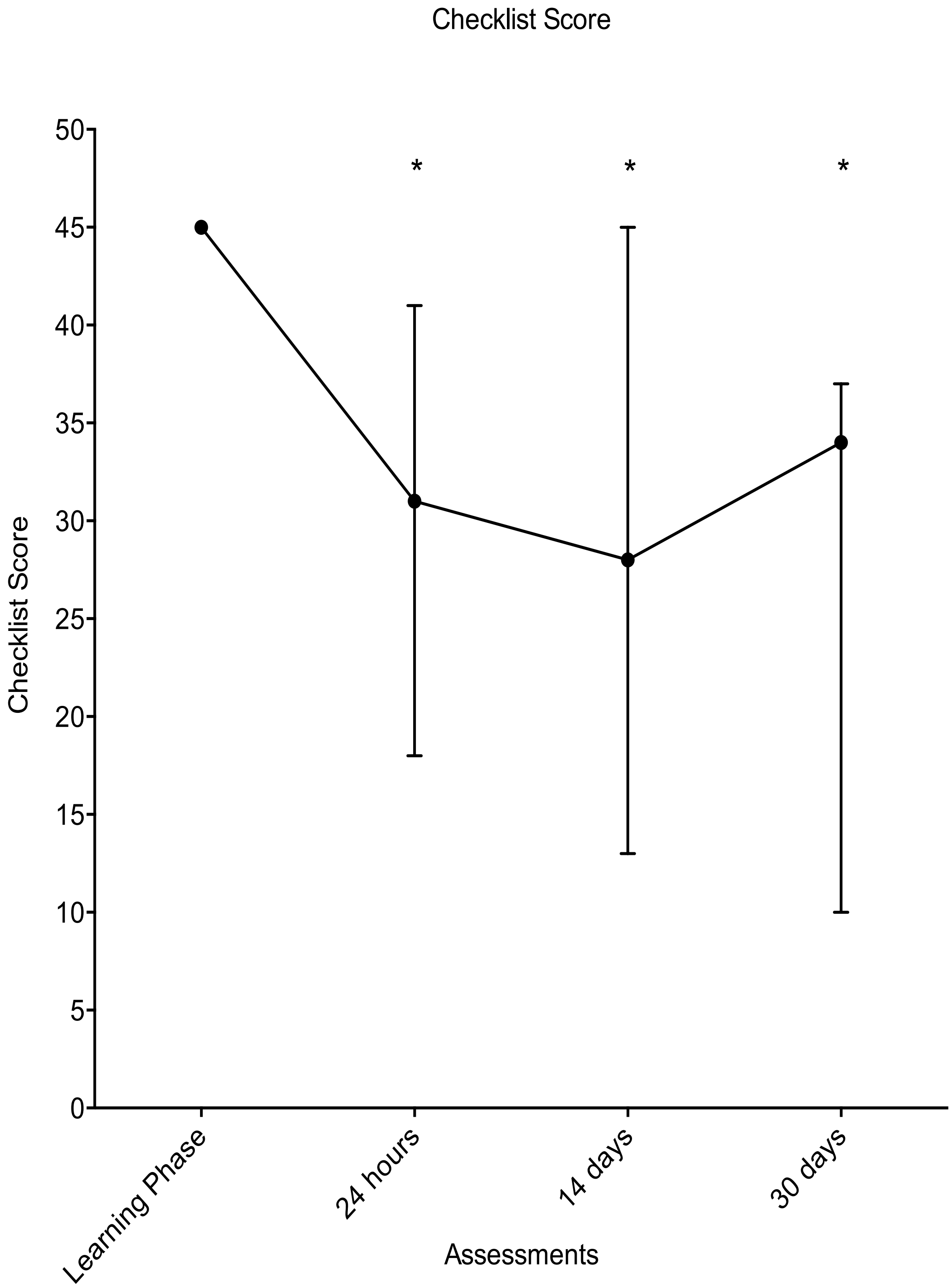
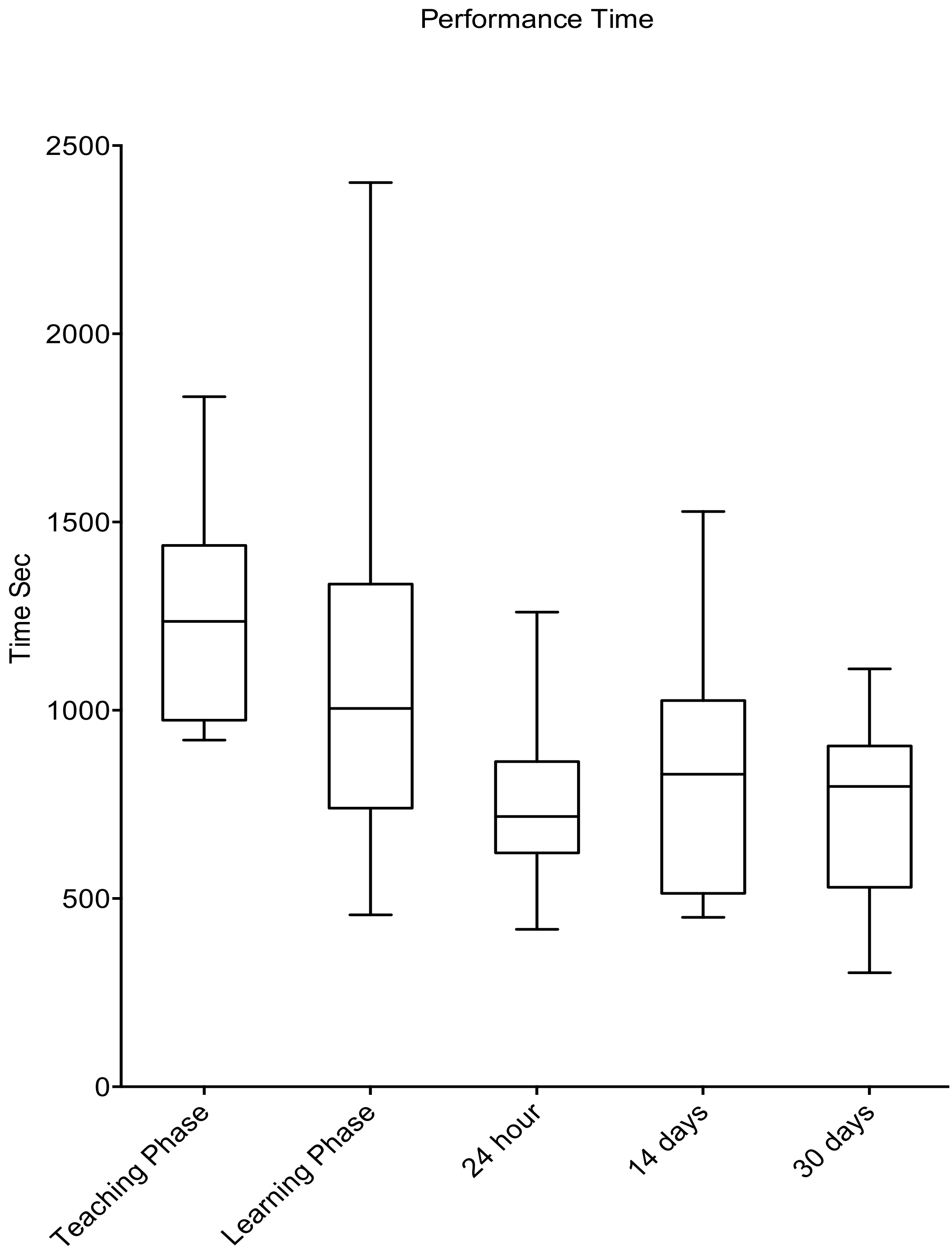


Figure 2: Performance Time: Box-Whisker plots of the Teaching Phase, Learning Phase and assessment interval at 24 hours, 14 days and 30 days with time in seconds. The middle bar in the box is the mean, the top of the box is the upper quartile, and the bottom of the box is the lower quartile. The top whisker is the maximum value, and the bottom whisker is the minimum value.



9.5 Discussion

The most important finding in this study is the degree of loss in learned skills (checklist scores) over a relatively short time.

The published literature on this demonstrates some variability. A study using a high fidelity simulator for emergency management demonstrated modest retention of skill (based on a ten-point checklist) even after one year[12]. Another study demonstrated immediate improvement after training but a significant decrease over six weeks for OSATS score for knots tying[13].

This study also demonstrated that after a standardized teaching session, the more experienced anaesthetist required more time to learn a skill, i.e. the greater one's years of experience, the longer it took to acquire the skill and the greater the degree of skill attrition at 24 hours.

The observation that more experienced (and generally older) clinicians tend to learn new skills more slowly/ less completely is consistent with research carried out in other medical specialties[14, 15]. Similarly other industries, aviation, have suggested a deterioration in the psychomotor and perceptual process with age[16]. Repetitive practice may be used to improve retention of skill[15].

This study was not performed to identify a specific age at which learning a new procedural skill is no longer feasible. For the purpose of this study we assumed that greater number of years of experience in anaesthesia practice that a participant has indicated a older age. The study findings did demonstrate the highly significant level of skill attrition that occurs following an intensive training course in practitioners of varying age and experience.

The baseline psychometric test that were used included the Purdue Peg Board, this was used for gross and fine motor movement and co-ordination; Cube Comparison for spatial orientation; Snowy Picture for speed of closure, ability to identify partially hidden objects; Shape Memory test for memory and visual recognition[9]. These test were selected specifically in relation to ultrasound imaging and fine movement required for the procedure.

The study conforms to the design recommendations for investigation of the effects a training program[17]. All aspects of the LP as well as the assessments were standardized (including the environment, the live model, the training program, the trainer, the feedback provided and the sequence of events). There was a degree of over-learning in the LP, same sequence of events for all four nerves. Over-learning is known to have a positive effect on retention of knowledge and skill [17]. Over-learning provides additional training; hence greater degree of learning is achieved. Furthermore over-learning gives a trainee more confidence in performance and reduces factors that may affect performance during retention tests (e.g. stress, anxiety) [17].

The checklist used was modified from its original version with the help of the HTA[8]. This was done so as to expand on the nerve identification using ultrasound. Because there was no intervention involved the interventional part of the checklist was excluded.

A number of limitations apply to this study. Although topographical variations in the anatomy of the brachial plexus occur in the axilla, all training and assessment were done on a normal axilla (same model). No attempt was made to confirm transfer of the benefits of the training program into clinical practice. To assess "true learning", it has been suggested that trainees should have interval training and then assessment[18]. Our study was designed to reflect the widespread practice of attending short training courses without structured application of the learned skills subsequently.

In conclusion, significant attrition in newly acquired skills is apparent within 24 ours of an intensive training course. In general, the longer one's experience in anaesthetic practice the longer it takes to acquire new procedural skills (at-least those described above). These findings may have important implications for design of intensive courses for medical procedures as well as for the participants of these courses, keeping in mind the increasing number of mature students going through medical training. The course designers should realize that the individual participant needs should be addressed if true learning is to happen. The large magnitude of attrition of learned skill over a relatively short period of time is something that needs to be recognized and addressed, be it interval teaching and/or interval assessment for retention of skills.

Future research should be directed towards identifying factors that will hasten and improve skill acquisition, prolong skill retention and delay skill attrition in novices.

9.6 References

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10 Conclusion and future direction

The work carried out in this thesis brings to light a number of important facts. The presence or rather absence of valid assessment tools for medical procedures should be addressed. If we are to move towards patient centered-competency-based assessment in practice[1], there should be a presence of valid objective assessment tools for medical procedures. The concept of construct validity implies that over time as more traits or performance qualities are identified, construct validity be updated [2] and further work needs to be conducted to introduce appropriate weighting of the individual points of a clinical assessment tool.

Simulation may be part of the solution[1]. Simulation provides a safe, stress free environment for trainees for skill acquisition, generalization and transfer via deliberate practice[3]. Trainees can acquire skill sets from different simulators according to their level of training[4]. The numbers of simulators are ever increasing although there is a deficit in the validation process for these simulators.

The effect of feedback based on knowledge of performance was associated with an increase in the speed of skill acquisition and a decrease in error rate during initial learning. Feedback based on knowledge of results was associated with a greater decrease in time needed for skill acquisition but not a lesser error rate during learning. Interestingly, the content of feedback provided was an important determinant of early (24 hour after initial learning) skill attrition.

The timing of feedback was associated with effective learning of skill. Interestingly those provided with feedback on demand (immediate feedback) achieved similar amounts and rates of learning with fewer feedback "events" than those who received delayed feedback. A marked attrition of skills was demonstrable 24 hrs after they have first been learned; the magnitude of this attrition was similar in both groups.

Using the principles of feedback as described above, when studying the effect of an intense training program on novices of varied years of experience in anaesthesia (i.e. the present training programmes / courses of an intense training day for one or more procedures). There was a marked attrition of skill at 24 hours; there also appeared to be an inverse relationship between years of experience in anaesthesia and performance. Greater the years of experience the longer it takes for teaching and learning.

Research in other specialties have also demonstrated the importance of using objective checklists and global rating scales for safety and assessment[5,6,7]. Attrition of skill has been likewise demonstrated, but over a longer time interval[8, 9,10,11].

The use of checklists is well established in non-medical industries such as airlines, space programmes, energy and automotive industries The use of checklists have demonstrated increased safety and proficiency in work as well as maintaining competency in training[12, 13].

There is an increasing need for clinical assessment tools for medical procedures. Further research need to be focused on defining the skills, developing appropriate metrics and assessing the reliability and validity of these metrics[14]. This may help the trainers, trainees and training bodies not only in skill acquisition but also in maintaining competencies.

The constructivist theory says that "learning is successful when the gap between actual and intended knowledge of trainees is identified and training is structured so that participants can sense make and problem solve to reduce this gap"[15,16]. This makes simulation ideal as it allows the trainee to learn and practice in a safe environment. Courses may be designed such that the trainee has the opportunity to learn and then apply the knowledge in a clinical setting. This may require co-ordination between the course directors and clinical practice managers. This co-ordination will greatly facilitate the learning of procedural skills in medicine (including those required for peripheral nerve blockade) and transfer of the benefits into clinical practice. This will be challenging in particular as it will require integration of didactic, simulation-based and clinical training to deliver a comprehensive and patient-focused curriculum.

The findings of the studies described in this thesis may have important implications for the trainers, trainees and training bodies in the design of present courses, introductory and otherwise, for novices as well as for participants learning new skills. No two trainees are the same; hence their requirements are different as well. This need to be recognized and courses need to be modified/ designed to address the individual learning needs of the trainee. This may be in the form of course content, time needed to teach, interval/ periodic teaching, forming tools for regular assessments and co-ordination between trainees/ learners, program directors and course coordinators, so as to provide the appropriate clinical workload.

Future research should also be directed towards identifying factors that may hasten skill acquisition, prolong skill retention or alternatively delay skill attrition.

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Appendix 1: Task Specific Checklist for Ultrasound Guided Axillary Brachial Plexus Block

Yes/No

1. Conduct clear pre-procedural consultation with patient ☐☐
2. Obtain informed consent ☐☐
3. Secure IV Access ☐☐
4. Apply monitoring ☐☐
5. Prepare equipment and emergency drugs for standard regional anaesthesia procedures ☐☐
6. Availability of trained assistant ☐☐

Positioning

7. Exposure of the axilla ☐☐
    - The subjects dignity should be maintained
    - The arm should be out of the sleeve
    - Axilla and shoulder should be completely exposed
8. Positioning of arm ☐☐
    a. Abduction - 90° at the shoulder
    b. Flexion – flexion of arm at the elbow
    c. External rotation – external rotation of arm
    d. Patient comfort ☐☐
9. Positioning of Equipment
    a. Ultrasound Screen ☐☐
        - Ultrasound machine screen should be in the same field of vision as the ultrasound probe
    b. Sterile Trolley ☐☐
        - Sterile trolley should be within in arms distance and within the same field of vision as the ultrasound machine screen and the ultrasound probe

Preparation

10. Preparation of local anaesthetic
    a. Identity ☐☐
    b. Concentration ☐☐
    c. Expiry ☐☐
11. Preparation of needle
    a. 22G gauge, 50mm Stimuplex needle (Standardized)
    b. Needle flushed ☐☐

12. Preparation of Ultrasound Probe
    a. Protection of probe ☐☐
        - Probe should be covered with either a sheath or a protective covering
    b. Application of gel ☐☐
        - Gel can be applied to either axilla or ultrasound probe

17.

Block

13. Preparation of Axilla
    a) Antiseptic solution should be applied in the axilla ☐☐

14. Application of Ultrasound Probe
    a. Orientation of probe ☐☐
    b. Probe placed perpendicular to the arm in upper axilla ☐☐
    c. Stabilizes transducer hand by resting gently on the patient ☐☐

15. Identification of Anatomical Structures
    - The participant will at this stage point at the ultrasound screen and identify the individual anatomical structures
    a. Axillary Artery ☐☐
    b. Axillary Vein/s ☐☐
    - The Axillary artery and vein should be identified via colour flow analysis
    c. Coracobrachialis muscle ☐☐
    d. Musculocutaneous Nerve ☐☐
    e. Median Nerve ☐☐
    f. Ulnar Nerve ☐☐
    g. Radial Nerve ☐☐

16. If using long axis approach maintain the needle in plane keeping whole needle in view at all times ☐☐
    If using short axis approach check needle tip position by frequent aspiration, injection of small volume or by gentle ossicilation to verify needle position

17. Deposition of Local Anaesthetic
    - For each nerve **(v) further dose injection** – the spread of Injectate should be visible on ultrasound screen
    a. Nerve 1__________
        i. Needle tip is identified ☐☐
        ii. Aspiration ☐☐
        iii. Test Dose (spread of injectate identified) ☐☐
        iv. Patient comfort on injection ☐☐
        v. Further dose injection ☐☐
    b. Nerve 2__________
        i. Needle tip is identified ☐☐
        ii. Aspiration ☐☐
        iii. Test Dose (spread of injectate identified) ☐☐
        iv. Patient comfort on injection ☐☐
        v. Further dose injection ☐☐

18.

c. Nerve 3__________
   i. Needle tip is identified ☐☐
   ii. Aspiration ☐☐
   iii. Test Dose (spread of injectate identified) ☐☐
   iv. Patient comfort on injection ☐☐
   v. Further dose injection ☐☐
d. Nerve 4 __________
   i. Needle tip is identified ☐☐
   ii. Aspiration ☐☐
   iii. Test dose (spread of injectate identified) ☐☐
   iv. Patient comfort on injection ☐☐
   v. Further dose injection ☐☐

Assessment

18. Wound stabilization device removed ☐☐
    - Dressing/ cast should be removed before assessment
      Patient should asked about pain before removing device
19. Musculocutaneous Nerve
    a. Sensory ☐☐
       - Lateral aspect of forearm should be checked for cold sensation
    b. Motor ☐☐
       - Forearm Flexion
20. Radial Nerve
    a. Sensory ☐☐
       - Posterior forearm, dorsum of hand, thumb, index and middle finger should be checked for cold sensation
    b. Motor ☐☐
       - Wrist and finger Extension
21. Median Nerve
    a. Sensory ☐☐
       - Anterior and medial aspect of forearm, thumb, index, middle and half of ring finger should be checked for cold sensation
    b. Motor ☐☐
       - Flexion of lateral two fingers
22. Ulnar Nerve
    a. Sensory ☐☐
       - Medial aspect of hand on the hypo-thenar eminence, little, ring and middle finger should be checked for cold sensation
    b. Motor ☐☐
       - Thumb opposition or finger abduction

Total Time taken: ______________
- Time will be measured in minutes- starting from the start of the video recording as per protocol and ending with the end off assessment.

NOTE:
Regarding 10.
For each nerve **(v) further dose injection** – the spread of Injectate should be visible on ultrasound screen

CLEARLY IDENTIFIED OBSERVABLE BEHAVIOR
i.e. can be identified if seen by assessor on videotape

<u>Contingency Factors</u>

In the event that one or more of the events described below occurs, please indicate by ticking the relevant box *Yes* or *No,* whether the learner performs appropriately:

1. Remains aware of the possible need for sedation or early GA as required☐☐

2. Seeks ultrasonographic and clinical signs of intraneural injection and responds appropriately ☐☐

3. Observes for spread of local anaesthetic solution: if not visualized stops injecting and assumes intravascular injection ☐☐

4. Recognizes inadequate block and supplements appropriately ☐☐

5. Recognizing a failed block, explains this to patient prior to proceeding to general anaesthesia ☐☐

Total = 63

APPENDIX II

Appendix 2: Generic Technical Skills Global Rating Scale[7,8]

Respect for Tissue	**1**	**2**	**3**	**4**	**5**
	Frequently used un-necessary force on tissue or caused damage		Careful handling of tissue but occasionally caused inadvertent damage		Consistently handled tissue appropriately with minimal damage
Time and Motion	**1**	**2**	**3**	**4**	**5**
	Many un-necessary moves		Efficient time/motion but some un-necessary moves		Clear economy of movement and maximum efficiency
Instrument Handling	**1**	**2**	**3**	**4**	**5**
	Repeatedly makes tentative or awkward moves with instruments by inappropriate use of instruments		Competent use of instruments but occasionally appeared stiff or awkward		Fluid moves with instruments and no awkwardness
Knowledge of Instrument	**1**	**2**	**3**	**4**	**5**
	Frequently asked for wrong instruments or used inappropriate instrument		Knew names of most instruments and used appropriate instruments		Obviously familiar with the instruments and their names
Flow of Procedure	**1**	**2**	**3**	**4**	**5**
	Frequently stopped procedure and seemed unsure of next move		Demonstrated some forward planning with reasonable progression of procedure		Obviously planned course of procedure with effortless flow from one move to the next
Use of Assistants	**1**	**2**	**3**	**4**	**5**
	Consistently placed assistants poorly or failed to use		Appropriate use of assistants most of the times		Strategically used assistants to the best advantage at all times
Knowledge of Procedure	**1**	**2**	**3**	**4**	**5**
	Deficient knowledge		Knew all important steps of operation		Demonstrated familiarity with all aspects of operation/ procedure
Overall Performance	**1**	**2**	**3**	**4**	**5**
	Very poor		Competent		Clearly superior

Overall in this task, should the candidate ☐ Pass ☐ Fail?

Appendix III

Skill set associated with Proficiency			
Understanding Ultrasound Image Generation and Device Operations	**Image Optimization (Non-Device Related)**	**Image Interpretation**	**Needle Insertion and Injection**
Understanding basic technical principles of image generation Selection of the appropriate transducer Selection of the appropriate depth and focus settings Understanding and appropriate use of both time gain compensation and overall gain Understanding and application of color Doppler Archiving images	Learn the importance of transducer pressure Learn the importance of transducer alignment Learn the importance of transducer rotation Learn the importance of transducer tilting	Identify nerves Identify muscles and fascia Identify blood vessels, distinguish artery from vein Identify bone and pleura Identify common acoustic artifacts Identify common anatomic artifacts (pitfall errors) Identify vascularity associated with needle trajectory	Learn the in-plane technique, maximizing needle visualization Learn the out-of-plane technique Learn the benefits and limitations of both techniques Learn to recognize intramuscular needle location Learn to recognize correct and incorrect local anesthetic spread Conduct proper ergonomics Minimize unintentional transducer movement Identify intra-neuronal needle location

Appendix IV

Script

Hello

Thank you for participating in this project. We will be giving you straightforward instructions on what to do.

This is the ultrasound machine with which you will be working.

Before starting please make sure the machine is plugged into a power socket.

Open the screen of the machine as shown and turn the machine on using the On/Off button, situated on the top left corner of the keyboard.

Hold the probe in your non-dominant hand between your thumb and index finger close to the probe's surface or footprint. As you might hold a pen or pencil.

Apply ultrasound gel to the probe footprint, use enough to cover the rubber strip on the ultrasound probe head.

Use the plastic stylet provided to check the orientation of the probe by gently moving the ultrasound gel on the probe head at the right corner of the probe.

Orient the probe so that the right side of probe corresponds to the right side of the screen. If necessary turn the probe 180° and check again.

Once you have the correct orientation of the probe with the ultrasound machine screen, apply the probe to the phantom model provided.

Scan the phantom model by gently applying the ultrasound probe, starting at one end of the model.

Ensure that the ultrasound probe remains in contact with the phantom surface by applying gentle pressure.

Move the probe across the phantom to find the "Hidden Target". Once you have identified the target structure, immobilize the hand and probe as shown.

Ensure the target structure is in the centre of the screen.

Increase or decrease the depth of the ultrasound beam by using the "DEPTH" button on the ultrasound machine and identify the exact depth using the graduation on the right side of the screen.

The depth button is situated on the top left of the mouse pad on the ultrasound machine.

Please say the depth of the target.

Once you have the target on the screen, use the color doppler to check for blood or fluid flow in the target structure.

This is the second button in the bottom right corner of the ultrasound machine, marked “COLOR”.

Hold the needle in your dominant hand in between your thumb and index finger as you would hold a pencil.

Insert the needle in the model keeping the needle in-line or in-plane with the ultrasound probe, as shown.

The ultrasound beam is 1 millimeter thick and runs along the centre-line of the ultrasound probe head, make sure that the needle is directly beneath of the ultrasound probe.

Watch the ultrasound screen to see the needle approaching the target structure as shown.

If the needle is not visualized, stop advancement of the needle, instead move or angle the ultrasound probe to search for the needle.

Only advance the needle when you have the needle tip and shaft visualized on the ultrasound screen.

Approach the target structure, keeping the needle tip and shaft in view at all times.

To change angle of approach withdraw needle at-least half way before adjusting the needle trajectory.

Once you have appropriately positioned the needle near the target structure and identified the needle tip, ask your assistant to aspirate the syringe.

Next inject a small quantity of solution. You can ask the assistant present to aspirate and inject.

Observe the pattern of injectate spread. Ideally the injectate should spread around the target, as shown. If necessary reposition the needle tip to facilitate this pattern of injectate spread.

Appendix V

Positioning

1. Exposure of the axilla ☐☐
    - The subjects dignity should be maintained
    - The arm should be out of the sleeve
    - Axilla and shoulder should be completely exposed
2. Positioning of arm ☐☐
    - Abduction - 90° at the shoulder
    - Flexion – flexion of arm at the elbow
    - External rotation – external rotation of arm
    - Patient comfort ☐☐
3. Positioning of Equipment
    - Ultrasound Screen ☐☐
        - Ultrasound machine screen should be in the same field of vision as the ultrasound probe

Scout Scan

4. Application of Ultrasound Probe
    - Orientation of probe(Biceps should be on the left side of screen ☐☐
    - Probe placed perpendicular to the arm in upper axilla ☐☐
    - Stabilizes transducer hand by resting gently on the patient ☐☐

5. Identification of Anatomical Structures
    - The participant will at this stage point at the ultrasound screen and identify the individual anatomical structures

    a. Axillary Artery ☐☐
    b. Axillary Vein/s ☐☐
    - The Axillary artery and vein should be identified via colour flow analysis

    c. Musculocutaneous Nerve ☐☐
    d. Median Nerve ☐☐
    e. Ulnar Nerve ☐☐
    f. Radial Nerve ☐☐

Musculocutaneous Nerve

- Starts in axilla ☐☐
    - If the nerve is lost and not readily identified return to the axilla, identify the median nerve and start the process of following its course again
- Identify Musculocutaneous Nerve ☐☐
- Keep nerve structure in centre of screen ☐☐
- Apply PART maneuver to optimize image ☐☐
- Follow musculocutaneous nerve distally ☐☐
- Follow musculocutaneous nerve proximally ☐☐
- Reconfirm nerve identity ☐☐
- Reconfirm anatomy ☐☐

Median Nerve

- Starts in axilla ☐☐
    - If the nerve is lost and not readily identified return to the axilla, identify the median nerve and start the process of following its course again
- Identify Median Nerve ☐☐
- Keep Median nerve in centre of screen ☐☐
- Apply PART maneuver to optimize image ☐☐
- Follow median nerve distally ☐☐
- Follow median nerve proximally ☐☐
- Reconfirm nerve identity ☐☐
- Reconfirm anatomy ☐☐

Ulnar Nerve

- Starts in axilla ☐☐
    - If the nerve is lost and not readily identified return to the axilla, identify the median nerve and start the process of following its course again
- Identify Ulnar Nerve ☐☐
- Keep nerve structure in centre of screen ☐☐
- Apply PART maneuver to optimize image ☐☐
- Follow ulnar nerve distally ☐☐
- Follow ulnar nerve proximally ☐☐
- Reconfirm nerve identity ☐☐
- Reconfirm anatomy ☐☐

Radial Nerve

- Starts in axilla ☐☐
    - If the nerve is lost and not readily identified return to the axilla, identify the median nerve and start the process of following its course again
- Identify Radial Nerve ☐☐
- Keep nerve structure in centre of screen ☐☐
- Apply PART maneuver to optimize image ☐☐
- Follow radial nerve distally ☐☐
- Follow radial nerve proximally ☐☐
- Reconfirm nerve identity ☐☐
- Reconfirm anatomy ☐☐