Regional anaesthesia update & Future directions in RA

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This is a condensed written version of my two talks for AQUA 2024. My first talk discusses training issues in regional anesthesia (RA) and ultrasound-guided regional anesthesia (UGRA), and how we currently assess competency in RA procedural skills. My second talk will introduce the technology of artificial intelligence (AI) and virtual reality (VR) and their current uses in UGRA.

Conflicts of interest

The VR system discussed in the second talk was developed by my research team as a non- commercial research tool. There are no financial conflicts of interest to declare. I have received honoria from GE Healthcare for speaking presentations.

1. Competency versus Expertise

The Dreyfus framework is a useful model to describe how medical professionals are first introduced to new procedural skills, gain competency through increased exposure and practice, before attaining expertise in that skill [1]. In our recent editorial [2], we used this framework to help illustrate the stages through which anaesthetists gain expertise in UGRA skills (Figure 1). The model describes five distinct stages of progression. When interpreted in the context of UGRA, the stages can be described thus: novice, characterised by rigid theoretical knowledge of sonoanatomy, needs close supervision for real-time skills of keeping the needle tip under vision while advancing; advanced beginner, who can complete simpler part-tasks of UGRA but not yet integrate part-tasks into a whole performance on the patient; competent, exhibits sufficient knowledge and dexterity to be independent for simpler blocks; proficient, where the block is seen in context of overall patient management, can change their block technique either in anticipation or in reaction to difficulties; and finally expert, characterised by authoritative knowledge and excellence with UGRA.

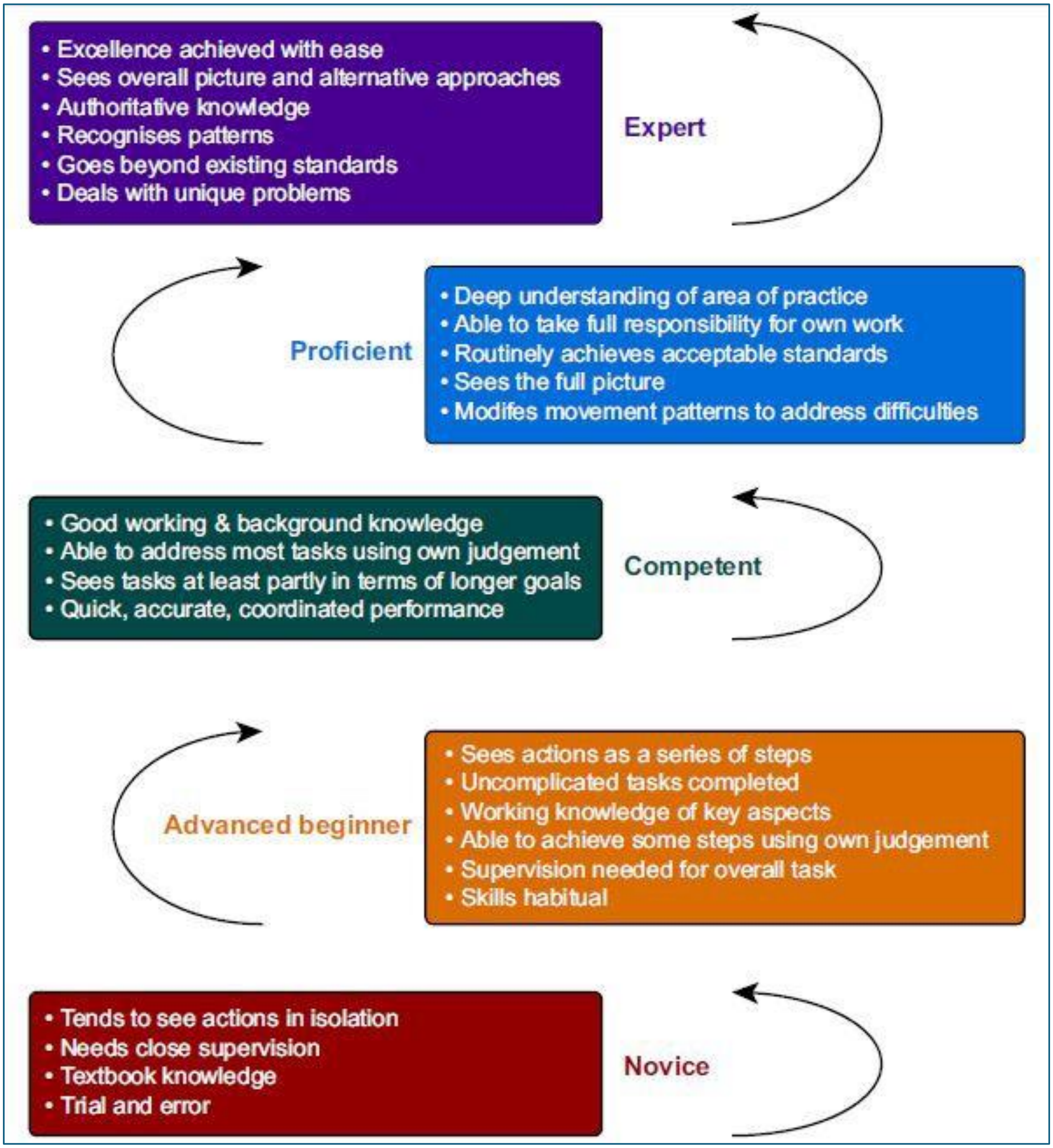

Figure 1. Dreyfus model of adult skill acquisition. Taken from [2].

2. Fellowship and non-Fellowship curriculum

RA fellowships are 6 to 12 months of dedicated exposure to RA, and by purpose aim to create experts in RA as described by Dreyfus. To achieve this outcome, Fellowship trainees are exposed to a greater variety and complexity of block techniques, increased caseload (volume of practice), enjoy protected time for teaching by expert faculty, and participate in academic activities such as research and when sufficiently trained themselves, supervising junior trainees in RA. Fellowship program recommendations and guidelines have been in North America [3] and Australia/New Zealand [4], with curricula learning objectives endorsed by their respective national RA societies.

In contrast, the purpose of non-Fellowship training is to graduate trainees at novice to competent levels. Where specifically along the Dreyfus continuum is ultimately stakeholder-driven, and these priorities are reflected in the minimum learning objectives and caseloads mandated by each national curriculum. Using ANZCA as the most relevant to this audience: there is a priority for FANZCAs to be at least competent in obstetric RA, hence the large caseload (70 spinals and 70 lumbar epidurals), but only novice-advanced beginner for peripheral limb RA (10 blocks for upper limb and 15 blocks for lower limb). By comparison, our Fellowship recommendations are for 80 upper limb and 80 lower limb blocks.

Given that non-Fellowship trainees have a severely limited exposure to RA, there arose a belief that instead of attempting to teach a broad range of blocks, there should be instead a focus on high value blocks. These could be described as blocks with a combination of: highest evidence of efficacy, highest safety margin for risk, easiest to teach and easiest to learn, and useful in a large variety of indications both for anaesthesia and analgesia. We performed a world-wide Delphi consensus project [5] that recruited 496 academic educators and clinical directors of RA training across 66 countries, resulting in selection of 4 peripheral blocks (interscalene, axillary, femoral, and popliteal sciatic) and 4 spinal/epidural blocks (Table 1) that satisfied the criteria to teach in a global non-Fellowship curriculum. Turbitt et al [6] described their selection of "best-bang-for-buck" blocks as the Plan A basic blocks in their editorial. This included the aforementioned 4 peripheral blocks and added adductor canal blocks and 2 trunk blocks (Erector Spinae Plane, ESP blocks, and rectus sheath blocks) (Table 2). Subsequent to this publication, RA-UK has endorsed the Plan A blocks and actively promotes it in the United Kingdom.

Items with highest importance and strong consensus
Regional anesthesia techniques
Interscalene brachial plexus block
Axillary brachial plexus block
Femoral nerve block
Popliteal sciatic nerve block
Landmark-guided lumbar spinal block
Landmark-guided lumbar epidural block
Landmark-guided combined spinal-epidural block
Landmark-guided thoracic epidural block

Table 1. Global consensus for highest value blocks in a non-Fellowship curriculum.

Table 1 Proposed high value basic ultrasound-guided regional anaesthetic techniques.

Anatomical location	Plan A (basic blocks)	Plan B/C/D (advanced blocks)
Upper limb		
Shoulder	Interscalene brachial plexus block [14]	Superior trunk block, combined axillary and suprascapular nerve blocks
Below shoulder	Axillary brachial plexus block [15]	Infraclavicular block, supraclavicular block
Lower limb		
Hip	Femoral nerve block [16]	Fascia iliaca block, lumbar plexus block
Knee	Adductor canal block[a] [17]	Femoral nerve block $\pm$ IPACK block
Foot and ankle	Popliteal sciatic block [18]	Ankle blocks, proximal sciatic nerve block
Trunk		
Chest wall	Erector spinae plane block [19]	Paravertebral block, serratus plane block, PECS blocks
Abdominal midline	Rectus sheath block [20]	Quadratus lumborum blocks

Table 2. Plan A blocks as editorialised by Turbitt et al.

3. Plan A blocks in ANZCA?

My personal belief is that it would be difficult to implement Plan A blocks in the current ANZCA curriculum. This is due to the severely restricted caseload of 10 (upper limb) or 15 blocks (lower limb), which in all studies of learning curves of acquiring RA skills shows that novices are still in the steep phase of procedural skills integration and also at highest risk of errors and complications (examples: [7-10]). To achieve a skill level closer to advanced beginner or competent, ANZCA trainees must instead go beyond the mandated minimum and be committed to pre-training in basic knowledge (anatomy, sonoanatomy, ultrasound knobology), out-of-hours workshops (optimising and recognising ultrasound scans, and part-task simulators to practice real-time needling skills), so that each clinical block experience is maximised. This is similar in principles to surgical technical skills training [11].

At a structural level, trainers can improve the quality of learning from this limited caseload by using assessment tools as part of formative assessment [12] and deliberate feedback [13].

4. Assessing UGRA skills

More than 20 different types of assessment tools have been developed to measure the performance of UGRA by anaesthetists. Of these, the most common in use in the workplace and simulation laboratory are checklists; either singly or paired with global rating scales [14]. The two most validated checklists are the "Cheung" checklist (named after the senior author [15]) originally developed for supraclavicular brachial plexus UGRA single shot blocks; and the Regional Anaesthesia Procedure Skills (RAPS) which was developed for all types of RA techniques including single shot to catheter, landmark/nerve stimulation or UGRA, peripheral and neuraxial [16].

Moreover, RAPS was designed to be anchored on ANZCA professional documents as well as including post-block care such as management of the insensate limb and transitional analgesia. The 25-item checklist is reproduced in Figure 2.

A major criticism of newly developed workplace-based assessment tools is low external reliability. Psychometric evaluation of tools requires a robust process of checking for the stability of scores between different assessors, due to the subjectivity inherent in assessing procedural skills. This phenomenon, often referred as "hawks vs doves" reduces the effectiveness of an assessment tool as a summative examination (high stakes, pass/fail) although this is of less significance if used for formative examination (used to structure feedback after performance from trainer to trainee).

All Blocks

1. Obtains informed consent as described by Professional Standards 26 and Professional Standards 03
2. Ergonomic positioning of patient, equipment, and proceduralist
3. Obtains intravenous access and applies monitoring as defined by Professional Standards 03
4. Appropriate combination of local anaesthesia, additives, or adjuvants
5. Chooses clinically appropriate needle
6. Sets up equipment properly, including ultrasound machine or neurostimulator
7. Skin asepsis and maintains sterility for that block as defined by Professional Standards 28
8. If providing procedural anxiolysis: maintains conscious sedation as defined by Professional Standards 09
9. Aspirates to check for blood/cerebrospinal fluid, uses incremental boluses, and re-aspirates between bolus
10. Checks for signs of systemic toxicity, intravascular injection
11. Checks for signs of potential intraneural injection

Catheter item

12. Correctly fixates and checks continuous infusion catheters/epidurals

Non-ultrasound-guided regional anaesthesia techniques

13. Locates correct surface anatomy/landmarks for block
14. Chooses appropriate needle insertion point and trajectory
15. Chooses correct current and motor endpoints during block if combined with neurostimulation

Ultrasound-guided regional anaesthesia techniques

16. Performs survey scan, identifies structures pertinent to procedure
17. Optimises nerve image by probe manipulation, nerve localisation techniques
18. Chooses appropriate needle insertion point, and trajectory to maintain in-plane ultrasound views
19. Demonstrates ability to locate needle tip in real time, throughout procedure
20. Recognises spread of local anaesthesia and adjusts needle positioning to optimise local anaesthesia distribution
21. Chooses correct current and motor endpoints during block if combined with neurostimulation

All blocks

22. Demonstrates knowledge of block onset and success by motor/sensory testing
23. Formulates and performs rescue block (as necessary)
24. Formulates perioperative analgesia plan
25. Formulates plan for care of blocked region, and postoperative follow up

Figure 2. 25-item validated checklist from the Regional Anaesthesia Procedure Skills (RAPS) tool.

Nonetheless, given that assessment tools are used to officially grade performance of trainees, the subjectivity inherent in a single time-point assessment is minimised by increasing the quantity of assessments spread over time and across different contexts, and scored by multiple assessors – hence the concept of a “portfolio” of workplace-based assessments.

5. Future of Assessment: Objective metrics?

Intriguingly, technology could assist in moving assessments away from subjective opinions and towards objectively measured metrics. In UGRA, two technologies have emerged that allows kinematics to be faithfully recorded as these are continuously measured by the computerised device. The first is eye-tracking technology, which in based on a wearable device that measures eye movements in real-time, recording metrics such as eye fixations, areas of interest (heatmaps), fixation sequences, and the time spent on each of these movements. These are overlaid over real- life visual fields of the wearer. Borg et al [17] and McLeod et al [10] have shown construct validation of eye tracking devices in UGRA, recording the wider variability of kinematics exhibited by novices compared to experts – see Figure 3 and 4.

The second technology is VR, which by nature of the fully computerised virtual environment must record all real-world kinematics and represent them in the virtual. As a consequence, these metrics can be downloaded and converted into learning curves for each individual. We have demonstrated this construct validation between novices and experts in our prototype VR needling simulator [18] (Figure 5).

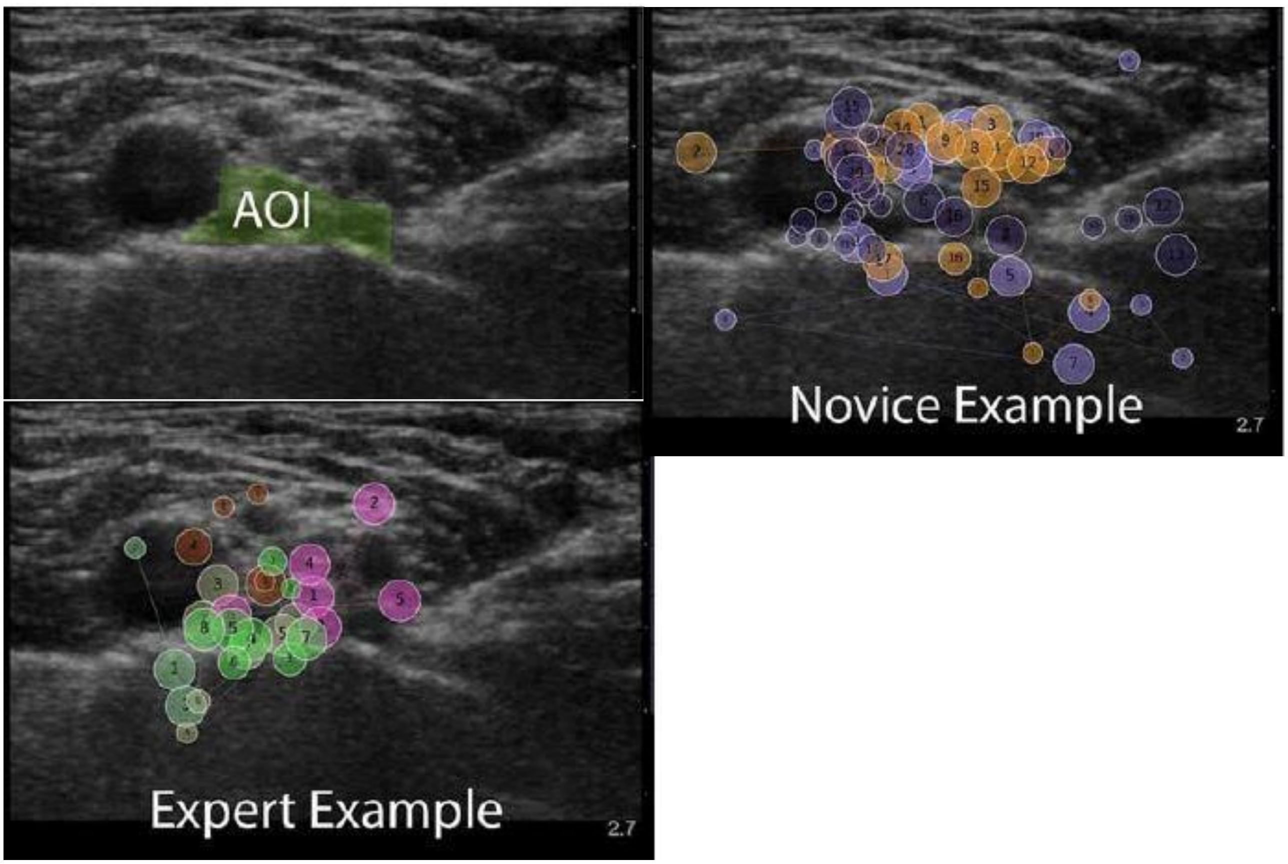

Figure 4. Eye gaze fixations and attention overlaid on actual real-life view of ultrasound machine.

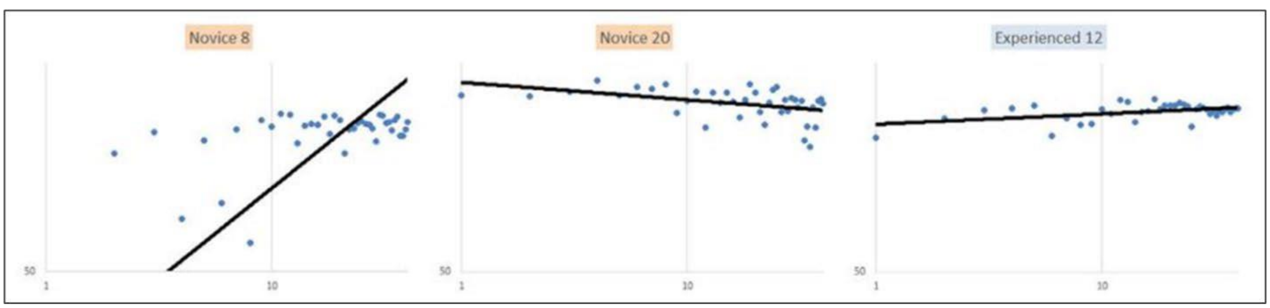

Figure 5. Individualised learning curves generated using hand movement kinematics recorded during VR-based simulation training for needling practice. Each score is based on angulation of the needle relative to the transducer, time taken to complete the procedural task, and number of withdrawals.

6. Using AI to assist sonoanatomical identification during UGRA

One strength of computer systems is their ability to rapidly process large amounts of data. Teaching the computer system to have a form of artificial intelligence so it can recognise relevant data and form conclusions from an enormous dataset is called *machine learning*.

When optimised for medical imaging applications, an AI system is taught using a *deep learning* process employing a *convoluted neural network* which mimics the same experiential learning that humans use to become experts [19]. In humans, over time and experience with hundreds and thousands of repetitions, we use pattern recognition and heuristics to recognise relevant features when we perform ultrasonography during UGRA (eg. nerve structures, muscles, fascial planes, arteries and veins, bony landmarks). Convoluted neural networks are multi-layer, hierarchical, but non-linear [20]; the AI system strips away resolution layers of each image (down-sampling) to better clarify salient landmarks, before rebuilding the layers (up-sampling). At each step, the AI compares its predictions against human experts who have already annotated the image as the gold standard. If predictions were incorrect, the AI re-iterates the process and adjusts the prediction algorithm accordingly. This re-iterative process typically requires several hundred thousand images for each nerve block location. There are now several commercially available AI systems that are available for UGRA, which overlays its prediction of structures over the ultrasound image (Figures 6 and 7).

Thus, the current application of AI in UGRA is for assisting in image interpretation. The most studied commercial AI system is ScanNav, with external validation between AI prediction rates versus human experts [21]. Rates of predictive success is very variable between the different Plan A block locations, with the worst performing being the axillary brachial plexus block [22]. These studies are all non-clinical, with no evidence yet from real world use-cases.

I provide some personal viewpoints from my own experience employing these first generation AI systems in clinical use: (1) the AI does not hesitate in providing an answer - much like the cognitive bias exemplified in the Dunning-Kruger effect, the AI can be seemingly overconfident in predicting structures; (2) the AI was taught using still images; but dynamic scanning “prescan” and “traceback” techniques resolves much of the uncertainty around structures in clinical use; (3) AI experiences *hallucinations* when faced with neurovascular variability; (4) AI is quite accurate at the “easy” scans but struggles with “difficult” scans – just like humans. Currently, assistive AI is useful as a teaching tool in novice UGRA practitioners while they are learning how to recognise sonoanatomy.

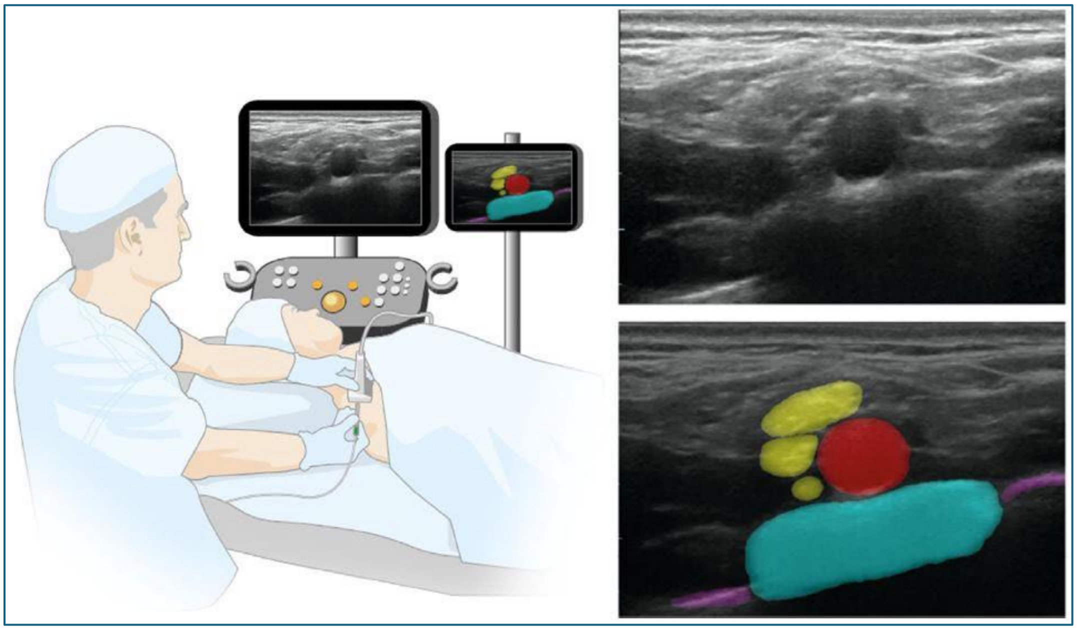

Figure 6. ScanNav (Intelligent Ultrasound, UK) system. A second slave monitor overlays the AI prediction over the ultrasound image.

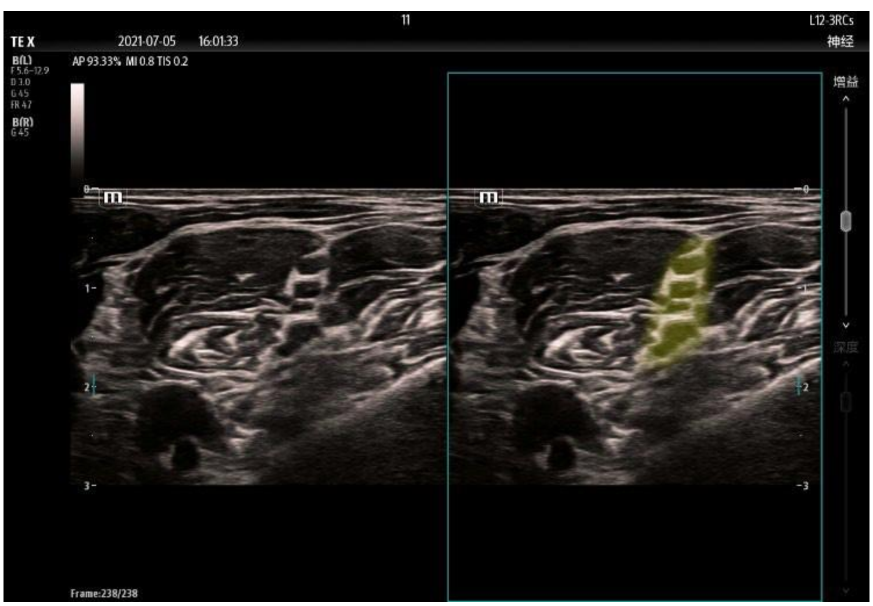

Figure 7. SmartNerve (Mindray, China) system. The screen divides into 2 views with the AI overlay over the second image.

7. Using VR to teach regional anaesthesia

VR is a computerised system that generates a 3D multisensory environment that replaces the real- world with a virtual world. Interaction within the virtual world occurs through hand motion controllers. When the VR system includes an occlusive headset that excludes real-world visual and auditory cues by virtual ones, and with specific hardware features (>90 degree field of view, >60 frames per second refresh rate, <20 millisecond latency, and at least 1080p resolution) there is sufficient *immersion* to feel transported into the virtual world.
These are high end VR systems called immersive VR (iVR) and has been used as a type of high fidelity simulator to teach both technical and non-technical skills, predominantly relating to surgical procedural skills [23,24]. We have designed and validated a iVR system [18] to teach novices real-time needling skills necessary in UGRA (Figures 8 and 9). This system uses a Meta/Oculus VR headset and gaming laptop to recreate a high fidelity part-task trainer with ultrasound transducer and needle. Construct validation between novices and experts has been established and learning curves (Figure 5) can be constructed during training sessions, leading to the possibility of tailoring training to the individual.

Figure 8. iVR virtual environment replicating an operating theatre

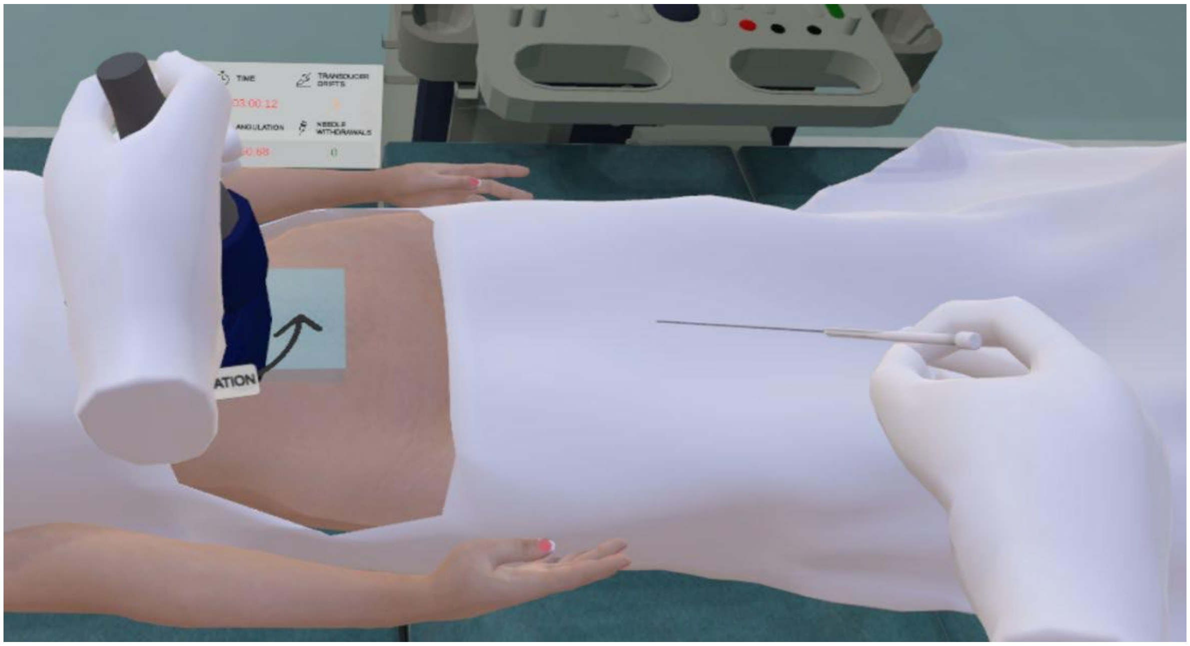

Figure 9. close up view of the iVR needling part-task simulator

We have since performed a RCT using the iVR simulator, comparing this to 1:1 deliberate practice (gold standard). While the iVR training did not show superiority, we found that faculty trainers were halved in the intervention group [25]. This finding will need further support in a non-inferiority trial that demonstrates that iVR can successfully substitute for faculty, with significant impact on reducing resources needed to teach UGRA. In my experience using iVR to teach UGRA, I have the following observations: (1) future generations of iVR should incorporate haptics to fully replicate the real-world experience of needling; (2) future studies need real world use cases and impact on educational outcomes and clinical outcomes; (3) nonetheless iVR provides an ideal opportunity to repetitively pre-train in dexterity, allowing novices to progress along the Dreyfus continuum towards competency and proficiency in a safe environment; (4) iVR simulators provide resource relief, allowing one faculty member to supervise more trainees at the same time during workshops.

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