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Prioritizing and Ranking Research Topics in Regional Anaesthesia Education and Training

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Abstract

Objectives: Education in regional anaesthesia covers several complex and diverse areas, from theoretical aspects to procedural skills, professional behaviors, simulation, curriculum design and assessment. The objectives of this study were to summarize these topics, and to prioritize these topics in order of research importance.

Design: Electronic structured Delphi questionnaire over 3 rounds

Setting: International

Participants: 38 experts in regional anaesthesia education and training, identified through the American Society of Regional Anesthesia Education Special Interest Group research collaboration.

Results: 82 topics were identified and ranked in order of prioritization. Topics were categorised into themes of simulation, curriculum, knowledge translation, assessment of skills, research methodology, equipment, and motor skills. 13 topics were ranked as essential research priority, with four topics each on simulation and curriculum, three topics on knowledge translation, and one topic each on methodology and assessment.

Conclusions: Researchers and educators can use these identified topics to assist in planning and structuring their research and training in regional anaesthesia education.

Strengths and limitations of this study

- This study lists the relevant topics in regional anesthesia education and training and ranked them in order of research importance
- Topics were formatted using British Medical Journal EPICOT guidelines, and ranked using prospective Delphi questionnaires
- Results of this study is from selected experts in regional anesthesia, and not surveyed from the entire anesthesia research community

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Introduction

Regional anaesthesia has increased in popularity, particularly since the introduction of ultrasound-guided techniques. In expert hands, current regional anaesthesia (RA) techniques have advantages of increased success, shorter onset time, reduced complications, reduced dose requirements, and cost-effectiveness, over traditional techniques.[1-3] Clinical expertise is in turn is a reflection on the effectiveness of RA education and training. The skillsets required for successful and safe RA are complex and diverse. With widespread uptake of ultrasound-guided regional anaesthesia (UGRA), these mandatory skillsets have increased. They include anatomy, physiology, pharmacology, sonoanatomy, identification and optimization of sonography images, needle visualization dexterity skills,[4-8] as well as professional attributes of communication, teamwork, decision making, and situational awareness.[9,10]

These technical skills have previously been published by the 2010 American Society of Regional Anesthesia (ASRA) and European Society of Regional Anaesthesia and Pain Therapy joint committees.[11] Furthermore, anaesthesia training programs are being re-structured from a time-based, to competency-based models. An example in North America is the 2014 regional anaesthesia competency milestones published by the American Board of Anesthesiology/Accreditation Council for Graduate Medical Education.[12]

Achieving these educational goals is a formidable challenge for our subspecialty. To assist in delivering this curriculum, ASRA established an Education Special Interest Group (SIG) in April 2017. This study was initiated through the SIG research collaboration, composed of a multidisciplinary and multinational co-operation between clinicians, medical educators, and psychologists.

This study has two objectives. The first objective is to help engagement of stakeholders (researchers, educationalists, clinicians, and research grant reviewers) by providing a list of the current diversity of education topics in RA education. Given the breadth of possible research activities, a second objective was to prioritise topics by order of research need. This prioritisation was performed by obtaining expert regional anaesthetists' opinions on which topics are most relevant for RA education.

This study used a Delphi method, in which rounds of questionnaires are sent to participants. Advantages include anonymity, minimising bias from strong personalities, equal weighting of all opinions, and not geographically restricted as electronic questionnaires are used. Similar prioritisation studies using this electronic Delphi method have been undertaken by other craft groups, including respiratory medicine, maternal/perinatal medicine, and clinical anaesthesia.[13-15] Our purpose in conducting this study is to prioritise scholarly attention and funding towards improving the evidence-base for initiatives in regional anaesthesia education.

Methods

This prospective study used questionnaires to rank, in order of prioritisation, research topics relevant to regional anaesthesia (RA) education and training. Structured electronic Delphi questionnaires were sent via e-mail to blinded participants. The study was performed between September 2017 and January 2018. There was no public or patient involvement in this study.

Study Participants

Potential participants were nominated by members of the research subcommittee of the ASRA Education SIG. The criteria for nomination was an established researcher or active contributor in RA education, evidenced by authorship of RA education journal articles and textbooks, directors of RA training programs, or as a member of national or international education committees and education working groups.

Nominees were invited via direct e-mail to participate in this study. The study rationale and protocol were provided. This study is a negligible risk, anonymous survey of anaesthesia clinical academics. After reading the invitation and the protocol document, informed consent was given by each participant providing an affirmative reply to the invitation and study protocol.

Research Topics in RA Education

To create a list of articles that encompasses research activities in RA education, we used the following source materials. Firstly, a prior narrative review of RA education studies by Nix et al,[8] contained a list of pertinent articles published up to August 2012. That review used the

following literature search terms: “ultrasound-guided regional anaesthesia, UGRA, regional, local, ultrasound, guided, education, training, mentor, in-service, local anaesthesia, anesthesiology, medical education, continuing medical education, graduate medical education, and postgraduate education, January 1982 to August 2012”. Using the same strategy, the National Library of Medicine and Medline databases were searched to update the list of relevant articles from September 2012 to August 2017. The World Health Organisation International Clinical Trials Registry Platform was also searched using combinations of the following terms: “Regional Anesthesia, Regional Anaesthesia, Anesthesiology, Anaesthesiology, Education, Training, Simulation”. Lastly, a grey literature search was performed with the parameters “teaching ultrasound-guided regional anaesthesia to residents/trainee anaesthetists/anesthesiologists”.

Together, these articles and research studies provided a body of work of previous and current research avenues in RA education and training. Text in all works was also scrutinised for other suggestions and implications for future research. Individual research topics were then re-written in EPICOT format (Evidence, Population, Intervention, Comparison, Outcome, Timestamp) using editorial guidelines from the British Medical Journal.[16]. This guideline seeks to present research recommendations in a format that emphasises specific research questions arising from available evidence. Both authors independently performed the tasks of reading through articles and re-writing the research topics in EPICOT format. After merging the list of topics, any differences between authors were jointly discussed to reach consensus.

Round One Screening

Three rounds of questionnaires were designed. In Round One, the initial list of EPICOT research topics were e-mailed to participants. A 10-point Likert scale was used to rate each presented topic. Participants were asked to score each topic on its own merits, and not to rate topics against each other. The Likert scale used text anchors against the following numerical scores to assist rating; 1 = Not recommended for further research, 4 = Some value for research, 7 = Important area for research, and 10 = Essential research. Participants could also provide suggestions for additional research topics in free text sections. Participants returned their Round One scores directly to study investigator AC. Aggregate scores from all participants were used to calculate the median score for each topic.

A priori thresholds were predefined to categorise topics. A median score of ≥ 6, and for which ≥ 60% of the panel scored ≥ 6, were included for final prioritisation in Round Three. Topics which scored a median ≤ 3 were excluded from further ranking.

Rounds Two and Three Prioritisation

Topics with median scores between 3 and 6 in Round One were re-ranked in Round Two, along with the additional topics suggested by participants in Round One. Participants were asked to now rank topics in relative importance to each other. To emphasise prioritisation of topics, the text anchor descriptions of the Likert scale were changed. Scores 1 to 3 were for topics of lowest research priority, 4 to 7 were for topics of intermediate priority, and 8 to 10 for topics of essential research priority. Topics which scored a median ≤ 3 were excluded.

Round Three was the final questionnaire and prioritised the topics identified as higher ranked in Round One, that is a median score ≥ 6 by more than 60% of participants. This round used the

same instructions and Likert scale as in Round Two. Figure 1 illustrates this Delphi methodology.

In all rounds, participants did not interact, nor were they aware of the identities of other participants. Study investigator AC had the only access to individual scores. Scores and comments were de-identified prior to analysis. Participants were given three weeks to score each round. Reminder e-mails were sent one week prior, and three days after, this deadline.

All scores were entered into a Microsoft Excel spreadsheet (version 2016, Microsoft Corp, Redmond, WA). Descriptive statistics were performed and reported as median scores with 25th to 75th interquartile range (IQR), and as the proportion of all participants who scored 6 or higher for each topic.

Results

Fifty-two e-mail invitations were sent. Thirty-eight participants (73%) accepted the invitation. Thirty-seven returned scores for Round One (97% response). All 38 participants returned scores for Rounds Two and Three (100% response). The 38 participants included 29 authors (76%) of journal articles and regional anaesthesia textbook contributions, 20 training program directors (53%), and 12 were also members of national or international education programs (32%).

In Round One, participants ranked the 74 initially generated topics. Fifty topics reached the threshold of higher priority scores and were included in Round Three. In Round Two, 24 intermediate ranked topics were scored, along with 8 new topics suggested by participants. Based on predefined criteria, no topic was excluded in either Rounds One or Two. A total of 82 topics were thus ranked in order of research priority in Round Three. These results are summarized in Figure 1.

Topics were categorised into seven themes: research on structure and design of a RA training curriculum; the effectiveness of equipment and *in vitro* models in training RA skill sets; assessment of RA knowledge and skills; knowledge translation from practice and lectures to RA performance in a clinical setting; research methodology and protocol design of RA education studies; research on development, retention, and proficiency of RA motor skills; and the role of simulation in RA education.

There were 13 topics ranked as "essential research priority" by participants, defined as median scores of 8 or higher in Round Three. These topics are listed in Table 1. There were 4 topics each on simulation and curriculum, 3 topics on knowledge translation, and 1 topic each on methodology and assessment.

Table 2 includes the next 24 topics scored as a 7, which is equivalent to the highest cohort of intermediate priority topics. Table 3 includes the 13 lowest ranked topics. The supplementary tables re-categorizes all 82 topics into the seven themes of curriculum (Table S1), equipment (Table S2), assessment (Table S3), knowledge translation (Table S4), methodology (Table S5), motor skills (Table S6), and simulation (Table S7).

Discussion

This study summarized the large and diverse body of research activities in regional anaesthesia education. These research activities were re-written as 82 research topics, and scored by a panel of expert participants who ranked these topics in order of importance. Thirteen topics were found to be of essential priority, and resolving these specific questions would advance our current understanding of RA education.

Four of these topics were on the role of simulation. Further evidence is required to inform appropriate learning objectives and competency milestones during simulation training. In turn, deliberate practice is the educational technique that describes repetitive practice using these pre-defined learning outcomes, with structured feedback by expert faculty.[17] While evidence for deliberate practice exists in RA ultrasound-guided needle guidance studies,[18,19] the effectiveness of deliberate practice in RA simulation training was identified as a priority research area. Determining whether simulation training ultimately influences patient outcomes such as improved safety, faster performance, and higher efficacy, versus traditional clinical exposure, were also regarded as priorities. Indeed, a recent systematic review of randomized controlled trials found only one study looked at patient outcomes after simulation training in regional anaesthesia.[6]

There were four curriculum topics ranked as essential. A description of a redesigned RA curriculum,[20] based on a framework for systematic training and assessment of technical skills,[21] has been previously published. Our study found, however, that further work is required to help define the characteristics of an ideal RA curriculum, including what are the core RA skill sets. Evaluation of success of the curriculum was also deemed to be a priority. Many institutions have dedicated RA “block rooms”, but measuring effectiveness of this initiative remains elusive. A

recent article, published after this study commenced, found that surrogate measures of analgesia, pain scores and opioid consumption were reduced after introduction of a block room.[22]

Questions remained about the ability of physicians to maintain RA knowledge and motor skills. This was identified as translation of skill sets between different RA procedures, and whether anesthetists (trainees or consultants) can retain new information learnt at workshops and simulation into clinical practice.

The two remaining essential priority topics were on assessment of the RA procedural skill. This involved defining the minimum competency for each RA task, and to reach consensus on which assessment tools should be used to evaluate competency. A systematic review has recently summarized the available assessment tools for RA procedures.[23]

The strengths of this prioritization exercise include using a prospective, structured, electronic Delphi technique. Expert regional anesthetists participated in categorising research topics over three iterative rounds of scoring, with an excellent response rate. The panel was international, with a large proportion contributing to the subspecialty as original journal authors and directors of RA training. The de-identified nature of scoring reduces bias from strong personalities influencing the consensus outcomes. Lastly, we pre-defined *a priori* thresholds for defining consensus, an important feature of robust Delphi studies.[24]

We thus believe that the essential priority topics identified in this study are clinically relevant to anaesthetists involved in RA education. For researchers, our results provide guidance on research activities that delivers highest clinical and educational impact. Conversely, we do not imply that research in lower ranked topics is discouraged. As examples, topics in the top 30 are still rated

highly by > 70% of participants and include questions on standardising outcome measures in RA studies, as well as characterising and remediating quality compromising behaviours by novices.

There are several limitations to our study. Participants in this study are active and passionate RA educators. Nonetheless, the sample size of 38 experts will not be representative of the entire RA research community. Even within this small panel, there were divergent opinions on the ranking of each topic, evidenced by relatively wide interquartile ranges. Surveying RA program directors in all RA societies world-wide may not necessarily provide a narrower result: the relative value each participant places on a specific topic will be influenced by their personal experiences and learning environments, and is a possible explanation of the differences in scoring. This subjective bias is minimized, but not fully removed, by imposing a minimum of two rounds of scoring for each topic, and by aggregating scores from all participants.

Each study in the Round One topic generation phase was treated independently when creating the EPICOT statements. This resulted in research topics with similar wording, and potentially could have been condensed. However, a strength of EPICOT is that the generated statements preserves context.[16] For example, the question "standardizing outcome measures in RA education" was ranked differently if related to assessment tools (rank 10), versus patient clinical outcomes (rank 14), and in a simulation context (rank 21). This allows researchers to help refine specific research activity.

The supplementary table reformats all 82 topics based on themes of curriculum, equipment, assessment, knowledge translation, methodology, motor skills and simulation. We caution that these themes are subjective and were categorised *post hoc*, as presented in the supplementary tables. During the prioritization phase, participants ranked topics without these thematic labels, and the tables were created only during manuscript preparation. Several topics could be

classified under multiple themes. Our results have been presented using thematic organization, as this may help researchers appreciate important directions and similarities within each theme.

In conclusion, we present results of a Delphi study designed to summarize, and then rank RA education topics in order of research priority. Experts in RA education, identified through a collaborative process within the ASRA Education Special Interest Group, were invited to participate. The 13 essential topics are diverse in nature, encompassing the role of simulation training, curriculum design, assessment of skills, and retention of skills, in regional anaesthesia. The complete list of 82 topics should be considered by researchers when deciding how best to concentrate their efforts in the advancement of education in our subspecialty.

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Figure Legends

Figure 1: Flow diagram of study, and summary of results at each Delphi round.

Table 1. Topics scored as essential priority, listed in rank order. Only topics scoring 8 or higher included. IQR; interquartile range

Overall Ranking	Topics	Theme	Median (IQR)	Proportion Scored ≥ 6
1	What endpoints/milestones should be achieved on a simulator prior to clinical performance of UGRA?	simulation	8 (7 – 9)	89%
2	Does simulation training show an improvement in clinical outcomes such as improved efficacy, time taken, and less errors?	simulation	8 (6 – 9)	89%
3	Which RA blocks should be considered as a core minimum set for all trainees? Are there benefits in teaching a subset of blocks to competency versus broader exposure to all blocks?	curriculum	8 (7 – 9)	87%
4	Is UGRA knowledge and technical skill generalisable: when does proficiency in one block type transfer to other blocks?	knowledge translation	8 (7 – 8)	87%
5	Does a rotation through a "block room" provide better learning than programs without a block room?	curriculum	8 (6.25 – 8)	82%
6	Is there a minimum number of blocks to attain proficiency for each block or are the skills transferable?	assessment	8 (6.25 – 8)	82%
7	Does simulation training bestow a safety advantage compared to proceeding directly to supervised practice in real patients?	simulation	8 (6 – 9)	82%
8	What criteria should be used to evaluate the success of an UGRA residency training curriculum?	curriculum	8 (6 – 8)	82%
9	What are the necessary components of a formal structured training programme?	curriculum	8 (6 – 8)	82%
10	What should be consensus assessment tools to standardise RA education research?	methodology	8 (6 – 8)	82%
11	What are the most efficacious means for practicing anesthesiologists (consultants) to learn blocks?	knowledge translation	8 (6 – 9)	79%
12	Does deliberate practice in simulation improve RA proficiency?	simulation	8 (5 – 8.75)	71%
13	How can trainees retain proficiency of knowledge and skills learnt after attending focused training (eg. RA rotation, simulation session, workshop)?	knowledge translation	8 (4.25 – 8)	71%

Table 2. Intermediate ranked topics. Only topics scoring 7 included. IQR; interquartile range

Overall Ranking	Topics	Theme	Median (IQR)	Proportion Scored ≥ 6
14	What should be consensus clinical endpoints to standardise RA education study endpoints?	methodology	7.5 (6 – 9)	87%
15	How do you maintain or improve knowledge retention after a one-day workshop?	knowledge translation	7.5 (6 – 8)	79%
16	Does the type and quality of feedback provided by faculty/tutors have an impact on learning outcomes?	simulation	7 (6 – 8)	87%
17	Does short duration courses/workshops result in long term changes in clinical practice?	knowledge translation	7 (6 – 8)	82%
18	What is the best way to establish multicentre collaborative studies in RA education?	methodology	7 (6 – 8)	79%
19	How can cusum methodology be used to track and provide quality assurance of RA clinical performance?	methodology	7 (6 – 8)	79%
20	Does pre-training (ie. Demonstrating competency of discrete tasks before further progression) result in improvement of RA knowledge and technical skills?	knowledge translation	7 (6 – 8)	79%
21	What should be consensus simulation/laboratory endpoints to standardise RA education study endpoints?	methodology	7 (6 – 8)	79%
22	What is the best way to teach sonoanatomy in “difficult” patients (eg. in the morbidly obese, patients with previous surgery)	curriculum	7 (6 – 8)	76%
23	What factors influence the common and recurring quality compromising behaviours observed in novices performing UGRA? What type of training is useful to remedy this behaviour?	motor skills	7 (6 – 8)	76%
24	How regularly does a trainee need to perform a block to be able to perform it independently after residency?	knowledge translation	7 (6 – 8)	76%
25	Is simulation training a cost-effective method of teaching, versus less resource-intensive alternatives?	simulation	7 (6 – 8)	76%
26	How can we best use web based/online resources (viewable content, social media, online assessments, video calls) to deliver	methodology	7 (6 – 8)	76%

	teaching?			
27	What is the optimum mix of lectures, workshops, courses, simulation and direct supervision required to teach RA?	curriculum	7 (5.25 – 8)	74%
28	How do you improve pre-clinical visuo-spatial skill (assuming that visuo-spatial skill is correlated with UGRA motor skills)?	motor skills	7 (5.25 – 8)	74%
29	What forms of instruction or strategies provide the most effective means of improving retention of sono-anatomy?	curriculum	7 (5.25 – 8)	74%
30	Does greater technical ability (proficiency) lead to better outcomes?	motor skills	7 (5 – 8)	71%
31	How do you improve poor coordination and fine motor control prior to clinical exposure?	motor skills	7 (5 – 8)	71%
32	Does pre-procedural knowledge or awareness of critical errors made by trainees, lead to a reduction in clinical errors by trainees?	knowledge translation	7 (5 – 8)	71%
33	Which tasks in UGRA require more resources, effort, and practice to gain competency?	methodology	7 (5 – 8)	71%
34	What are the factors promoting, and inhibiting, access to RA training?	curriculum	7 (5 – 8)	66%
35	Is simulation training more effective in some areas of RA education (eg. Knowledge retention versus technical skills) than in other areas?	simulation	7 (5 – 8)	63%
36	In resource poor countries, what is the best combination of textbooks, accessible online modules and videos, telemedicine, and live model scanning, to deliver a RA curriculum?	curriculum	7 (4 – 8)	63%
37	What are the contributing factors to the practice and impediment of trainees performing regional anesthesia after residency training?	knowledge translation	7 (4 – 8)	58%

Table 3. Lowest ranked topics. Topics scoring 5 or less included. IQR; interquartile range

Overall Ranking	Topics	Theme	Median (IQR)	Proportion Scored ≥ 6
69	Which blocks, or when, is neurostimulation best used to assist location of the needle tip?	equipment	5 (2.25 – 6)	47%
70	Does simulation training show an improvement in non-technical attributes such as communication, team work, professionalism and resource management?	simulation	5 (3 – 7)	47%
71	What is the best way to teach neuraxial sonoanatomy?	curriculum	5 (3.25 – 7)	47%
72	What is the best way to teach ergonomic principles and practices necessary for performing RA blocks?	curriculum	5 (3 – 7)	47%
73	In what situations is the learning outcomes from self-directed teaching no different from deliberate feedback?	assessment	5 (4 – 7)	45%
74	Does electromagnetic guidance modalities (radio-frequency tracking, needle magnetic currents) assist in needle tip and shaft localisation in UGRA?	equipment	5 (3 – 6.75)	42%
75	Which of the high fidelity cadaver models (ie. Thiel, fresh frozen, Batson, formalin) offer the best compromise between face validity, construct validity, availability, and cost?	equipment	5 (4 – 7)	42%
76	Which of the low fidelity phantoms (ie. gelatine, agar, tofu) offer the best compromise between face validity, construct validity, availability, and cost?	equipment	5 (4 – 7)	42%
77	Is there a role for a progression from low fidelity to high fidelity UGRA phantoms in teaching regional anaesthesia?	equipment	5 (3 – 7)	42%
78	Does 3D/4D ultrasound assist needle tip guidance in UGRA?	equipment	5 (2.25 – 6.75)	34%
79	Should we screen for technical and non-technical qualities predisposing to procedural skills proficiency, when selecting residents during the employment process?	assessment	4 (2 – 7.75)	39%
80	Which of the meat-based models (eg. pork, beef, turkey) offer the best compromise between face validity, construct validity, availability, and cost?	equipment	4 (3 -6)	32%

81	Do rigid needle trajectory guides (clip on accessory to transducers) assist in needle tip and shaft localisation in UGRA?	equipment	4 (3 – 6)	29%
82	Does robotic assistance aid needle tip positioning for RA?	equipment	3 (2 – 5.75)	26%

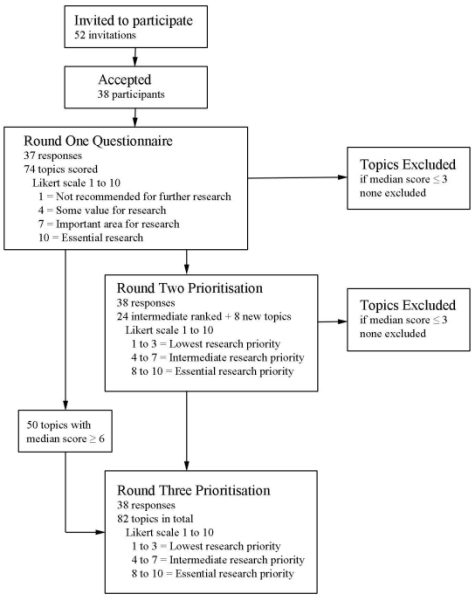

Figure 1: Flow diagram of study, and summary of results at each Delphi round.

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Supplemental Tables.

Table S1. Curriculum themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
3	Which RA blocks should be considered as a core minimum set for all trainees? Are there benefits in teaching a subset of blocks to competency versus broader exposure to all blocks?	8 (7 – 9)	87%
5	Does a rotation through a "block room" provide better learning than programs without a block room?	8 (6.25 – 8)	82%
8	What criteria should be used to evaluate the success of an UGRA residency training curriculum?	8 (6 – 8)	82%
9	What are the necessary components of a formal structured training programme?	8 (6 – 8)	82%
22	What is the best way to teach sonoanatomy in "difficult" patients (eg. in the morbidly obese, patients with previous surgery)	7 (6 – 8)	76%
27	What is the optimum mix of lectures, workshops, courses, simulation and direct supervision required to teach RA?	7 (5.25 – 8)	74%
29	What forms of instruction or strategies provide the most effective means of improving retention of sono-anatomy?	7 (5.25 – 8)	74%
34	What are the factors promoting, and inhibiting, access to RA training?	7 (5 – 8)	66%
36	In resource poor countries, what is the best combination of textbooks, accessible online modules and videos, telemedicine, and live model scanning, to deliver a RA curriculum?	7 (4 – 8)	63%
39	What standards of teaching should we expect faculty/tutors to attain? Should we assess the assessors for quality of teaching?	6.5 (5 – 8)	71%
41	Do 'teach the teacher' courses improve the ability to provide feedback and better assessment of RA procedural skills?	6.5 (4 – 7.75)	66%
49	Does provision of an "image bank" of sonoanatomy provide better learning than live model scanning?	6 (3.25 – 7)	63%
53	Does competency-based training improve patient outcomes compared to simulation-based training?	6 (5 – 8)	63%
56	What teaching tools or methodologies can be used to improve comprehension of sono-anatomy?	6 (5 – 8)	61%
61	How can we deliver teaching and support through the use of telemedicine technology? Can it be used as a follow-up for live-hands on sessions?	6 (5 – 7)	58%
71	What is the best way to teach neuraxial sonoanatomy?	5 (3.25 – 7)	47%
72	What is the best way to teach ergonomic principles and practices necessary for performing RA blocks?	5 (3 – 7)	47%

IQR; interquartile range

Table S2. Equipment themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
48	Which areas of teaching show no difference in learning outcome using cheaper low fidelity models, versus expensive high fidelity models? In what situations does higher fidelity models confer an advantage for learning?	6 (5 – 8)	63%
60	What are the roles of lower fidelity, versus higher fidelity, simulation practice in UGRA? Are higher fidelity models most appropriate when teaching difficult/complex blocks or when teaching advanced skills?	6 (5 – 8)	58%
62	Which models offer the best compromise between face validity, construct validity, availability, and cost, for ultrasound/fluoroscopy guided neuraxial/para-axial blocks?	6 (3 – 7)	55%
64	How does the use of eye tracking technology help in teaching RA?	6 (4 – 7)	55%
67	Can the use of hand motion technology help in teaching RA?	5.5 (4.25 – 7)	50%
68	Which echogenic needle technology provides the best visibility for UGRA procedures?	5.5 (3.25 – 7)	50%
69	Which blocks, or when, is neurostimulation best used to assist location of the needle tip?	5 (2.25 – 6)	47%
74	Does electromagnetic guidance modalities (radio-frequency tracking, needle magnetic currents) assist in needle tip and shaft localisation in UGRA?	5 (3 – 6.75)	42%
75	Which of the high fidelity cadaver models (ie. Thiel, fresh frozen, Batson, formalin) offer the best compromise between face validity, construct validity, availability, and cost?	5 (4 – 7)	42%
76	Which of the low fidelity phantoms (ie. gelatine, agar, tofu) offer the best compromise between face validity, construct validity, availability, and cost?	5 (4 – 7)	42%
77	Is there a role for a progression from low fidelity to high fidelity UGRA phantoms in teaching regional anaesthesia?	5 (3 – 7)	42%
78	Does 3D/4D ultrasound assist needle tip guidance in UGRA?	5 (2.25 – 6.75)	34%
80	Which of the meat-based models (eg. pork, beef, turkey) offer the best compromise between face validity, construct validity, availability, and cost?	4 (3 – 6)	32%
81	Do rigid needle trajectory guides (clip on accessory to transducers) assist in needle tip and shaft localisation in UGRA?	4 (3 – 6)	29%
82	Does robotic assistance aid needle tip positioning for	3 (2 –	26%

	RA?	5.75)	

IQR; interquartile range

Table S3. Assessment themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
6	Is there a minimum number of blocks to attain proficiency for each block or are the skills transferable?	8 (6.25 – 8)	82%
50	How do you identify the trainee with poor coordination and fine motor control?	6 (5 – 7)	63%
51	How do we best evaluate the non-technical skills of regional anaesthesia?	6 (5 – 7)	63%
52	Does using a didactic step-by-step checklist of sonoanatomical landmarks during scanning help novices learn sonoanatomy?	6 (4 – 7)	63%
55	What characteristics or attitudes do successful and unsuccessful UGRA performers possess?	6 (4 – 7.75)	61%
59	What is the role of the regional anaesthetists' teaching skill on residents performance?	6 (5 – 7)	58%
65	What characteristics or attitudes do effective teachers of UGRA possess?	6 (5 – 7)	55%
66	What is the role of coaches on improving the teachers of regional anaesthesia?	5.5 (3.25 – 7.75)	50%
73	In what situations is the learning outcomes from self-directed teaching no different from deliberate feedback?	5 (4 – 7)	45%
79	Should we screen for technical and non-technical qualities predisposing to procedural skills proficiency, when selecting residents during the employment process?	4 (2 – 7.75)	39%

IQR; interquartile range

Table S4. Knowledge translation themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
4	Is UGRA knowledge and technical skill generalisable: when does proficiency in one block type transfer to other blocks?	8 (7 – 8)	87%
11	What are the most efficacious means for practicing anesthesiologists (consultants) to learn blocks?	8 (6 – 9)	79%
13	How can trainees retain proficiency of knowledge and skills learnt after attending focused training (eg. RA rotation, simulation session, workshop)?	8 (4.25 – 8)	71%
15	How do you maintain or improve knowledge retention after a one-day workshop?	7.5 (6 – 8)	79%
17	Does short duration courses/workshops result in long term changes in clinical practice?	7 (6 – 8)	82%
20	Does pre-training (ie. Demonstrating competency of discrete tasks before further progression) result in improvement of RA knowledge and technical skills?	7 (6 – 8)	79%
24	How regularly does a trainee need to perform a block to be able to perform it independently after residency?	7 (6 – 8)	76%
32	Does pre-procedural knowledge or awareness of critical errors made by trainees, lead to a reduction in clinical errors by trainees?	7 (5 – 8)	71%
37	What are the contributing factors to the practice and impediment of trainees performing regional anaesthesia after residency training?	7 (4 – 8)	58%
57	What factors contribute to variability in understanding or identifying sono-anatomy?	6 (5 – 7)	61%

IQR; interquartile range

Table S5. Methodology themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
10	What should be consensus assessment tools to standardise RA education research?	8 (6 – 8)	82%
14	What should be consensus clinical endpoints to standardise RA education study endpoints?	7.5 (6 – 9)	87%
18	What is the best way to establish multicentre collaborative studies in RA education?	7 (6 – 8)	79%
19	How can cusum methodology be used to track and provide quality assurance of RA clinical performance?	7 (6 – 8)	79%
21	What should be consensus simulation/laboratory endpoints to standardise RA education study endpoints?	7 (6 – 8)	79%
26	How can we best use web based/online resources (viewable content, social media, online assessments, video calls) to deliver teaching?	7 (6 – 8)	76%
33	Which tasks in UGRA require more resources, effort, and practice to gain competency?	7 (5 – 8)	71%
43	What are the influences of the wide inter-individual learning curve in RA? Are any of these factors amenable to intervention?	6 (5 – 8)	68%
45	Should hierarchical task analysis be used to deconstruct and analyse each RA block for error rates?	6 (5 – 7)	63%
46	Would determining the learning style of trainees be helpful to assist in matching trainees to how best they learn content and type of content delivery?	6 (5 – 7.75)	63%
58	What is the best way to teach non-technical skills in RA, for example communication, professionalism, and resource management?	6 (4 – 7)	58%

IQR; interquartile range

Table S6. Motor skills themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
23	What factors influence the common and recurring quality compromising behaviours observed in novices performing UGRA? What type of training is useful to remedy this behaviour?	7 (6 – 8)	76%
28	How do you improve pre-clinical visuo-spatial skill (assuming that visuo-spatial skill is correlated with UGRA motor skills)?	7 (5.25 – 8)	74%
30	Does greater technical ability (proficiency) lead to better outcomes?	7 (5 – 8)	71%
31	How do you improve poor coordination and fine motor control prior to clinical exposure?	7 (5 – 8)	71%
42	Does a didactic step-by-step checklist, or proscribed method of transducer/needling technique, improve the quality of needle guidance?	6.5 (4.25 – 7)	58%
44	What is the importance of psychometric ability (visuospatial and psychomotor ability) on UGRA skills?	6 (5 – 7.75)	66%
47	What is the best way to teach out-of-plane needle approaches?	6 (5 – 8)	63%
54	What is the best way to teach needle guidance for neuraxial procedures?	6 (5 – 7)	61%

IQR; interquartile range

Table S7. Simulation themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
1	What endpoints/milestones should be achieved on a simulator prior to clinical performance of UGRA?	8 (7 – 9)	89%
2	Does simulation training show an improvement in clinical outcomes such as improved efficacy, time taken, and less errors?	8 (6 – 9)	89%
7	Does simulation training bestow a safety advantage compared to proceeding directly to supervised practice in real patients?	8 (6 – 9)	82%
12	Does deliberate practice in simulation improve RA proficiency?	8 (5 – 8.75)	71%
16	Does the type and quality of feedback provided by faculty/tutors have an impact on learning outcomes?	7 (6 – 8)	87%
25	Is simulation training a cost-effective method of teaching, versus less resource-intensive alternatives?	7 (6 – 8)	76%
35	Is simulation training more effective in some areas of RA education (eg. Knowledge retention versus technical skills) than in other areas?	7 (5 – 8)	63%
38	What is the best way to use augmented or virtual reality devices in RA simulation training?	6.5 (5.25 – 8)	74%
40	What is the best way to debrief using video recordings of trainee performance during simulation training?	6.5 (5 – 8)	68%
63	When is the best time during training to introduce simulation to novices learning RA?	6 (4 – 8)	55%
70	Does simulation training show an improvement in non-technical attributes such as communication, team work, professionalism and resource management?	5 (3 – 7)	47%

IQR; interquartile range

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Done
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Y
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Y
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Y
Objectives	3	State specific objectives, including any prespecified hypotheses	Y
Methods			
Study design	4	Present key elements of study design early in the paper	Y
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Y
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Y
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Y
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*Y*
Bias	9	Describe any efforts to address potential sources of bias	Y
Study size	10	Explain how the study size was arrived at	Y
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Y
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Y
		(*b*) Describe any methods used to examine subgroups and interactions	Na
		(*c*) Explain how missing data were addressed	Na
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Y
		(*e*) Describe any sensitivity analyses	Na

Results			**Done**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Y
		(b) Give reasons for non-participation at each stage	Y
		(c) Consider use of a flow diagram	Y
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Na
		(b) Indicate number of participants with missing data for each variable of interest	Y
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Y
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*Y*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*Na*
		Cross-sectional study—Report numbers of outcome events or summary measures	*Na*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Y
		(*b*) Report category boundaries when continuous variables were categorized	Na
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Na
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Na
Discussion			
Key results	18	Summarise key results with reference to study objectives	Y
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Y
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Y
Generalisability	21	Discuss the generalisability (external validity) of the study results	Y
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Y

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Research Priorities in Regional Anaesthesia Education and Training: An international Delphi consensus survey

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Research priorities in Regional Anaesthesia Education and Training: An international Delphi consensus survey

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Abstract

Objectives: Education in regional anaesthesia covers several complex and diverse areas, from theoretical aspects to procedural skills, professional behaviors, simulation, curriculum design and assessment. The objectives of this study were to summarise these topics, and to prioritise these topics in order of research importance.

Design: Electronic structured Delphi questionnaire over 3 rounds

Setting: International

Participants: 38 experts in regional anaesthesia education and training, identified through the American Society of Regional Anesthesia Education Special Interest Group research collaboration.

Results: 82 topics were identified and ranked in order of prioritisation. Topics were categorised into themes of simulation, curriculum, knowledge translation, assessment of skills, research methodology, equipment, and motor skills. 13 topics were ranked as essential research priority, with four topics each on simulation and curriculum, three topics on knowledge translation, and one topic each on methodology and assessment.

Conclusions: Researchers and educators can use these identified topics to assist in planning and structuring their research and training in regional anaesthesia education.

Strengths and limitations of this study

- This study lists the relevant topics in regional anesthesia education and training and ranked them in order of research importance
- Topics were formatted using British Medical Journal EPICOT guidelines, and ranked using prospective Delphi questionnaires
- Results of this study is from selected experts in regional anesthesia, and not surveyed from the entire anesthesia research community

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Competing interests: none declared

Authors contribution: AC and RR jointly conceived the study, wrote, and approved the final manuscript. AC performed data collection and statistical analysis.

Patient consent for publication: Not applicable

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Data sharing statement: No additional data available

Introduction

Regional anaesthesia has increased in popularity, particularly since the introduction of ultrasound-guided techniques. In expert hands, current regional anaesthesia (RA) techniques have advantages of increased success, shorter onset time, reduced complications, reduced dose requirements, and cost-effectiveness, over traditional techniques.[1-3] Clinical expertise is in turn a reflection on the effectiveness of RA education and training. The skillsets required for successful and safe RA are complex and diverse, especially with the widespread uptake of ultrasound-guided regional anaesthesia (UGRA). They include anatomy, physiology, pharmacology, sonoanatomy, identification and optimization of sonography images, needle visualization dexterity skills,[4-8] as well as professional attributes of communication, teamwork, decision making, and situational awareness.[9,10]

These technical skills have previously been published by the 2010 American Society of Regional Anesthesia (ASRA) and European Society of Regional Anaesthesia and Pain Therapy joint committees.[11] Furthermore, anaesthesia training programs are being re-structured from a time-based, to competency-based models. An example in North America is the 2014 regional anaesthesia competency milestones published by the American Board of Anesthesiology/Accreditation Council for Graduate Medical Education.[12]

Achieving these educational goals is a formidable challenge for our subspecialty. To assist in delivering this curriculum, ASRA established an Education Special Interest Group (SIG) in April 2017. This study was initiated through the SIG research collaboration, composed of a multidisciplinary and multinational co-operation between clinicians, medical educators, and psychologists.

This study has two objectives. The first objective is to help engagement of stakeholders (researchers, educationalists, clinicians, and research grant reviewers) by providing a list of the current diversity of topics in RA education. Given the breadth of possible research activities, a second objective was to prioritise topics by order of research need. This prioritisation was performed by obtaining expert regional anaesthetists' opinions on which topics are most relevant for RA education.

This study used a Delphi method, in which rounds of questionnaires are sent to participants. Advantages include anonymity, minimising bias from strong personalities, equal weighting of all opinions, and not geographically restricted as electronic questionnaires are used. Similar prioritisation studies using this electronic Delphi method have been undertaken by other craft groups, including respiratory medicine, maternal/perinatal medicine, and clinical anaesthesia.[13-15] Our purpose in conducting this study is to prioritise scholarly attention and funding towards improving the evidence-base for initiatives in regional anaesthesia education.

Methods

This prospective study used questionnaires to rank, in order of prioritisation, research topics relevant to regional anaesthesia (RA) education and training. Structured electronic Delphi questionnaires were sent via e-mail to blinded participants. The study was performed between September 2017 and January 2018.

Patient and Public Involvement

There was no patient or public involvement in this study.

Study Participants

Potential participants were nominated by members of the research subcommittee of the ASRA Education SIG. The criteria for nomination was an established researcher or active contributor in RA education, evidenced by authorship of RA education journal articles and textbooks, directors of RA training programs, or as a member of national or international anaesthesia education committees and anaesthesia education working groups.

Nominees were invited via direct e-mail to participate in this study. The study rationale and protocol were provided. This study is a negligible risk, anonymous survey of anaesthesia clinical academics. After reading the invitation and the protocol document, informed consent was given by each participant providing an affirmative reply to the invitation and study protocol.

Research Topics in RA Education

To create a list of articles that encompasses research activities in RA education, we used the following source materials. Firstly, a prior narrative review of RA education studies by Nix et al,[8] contained a list of pertinent articles published up to August 2012. That review used the following literature search terms: "ultrasound-guided regional anaesthesia, UGRA, regional, local, ultrasound, guided, education, training, mentor, in-service, local anaesthesia, anesthesiology, medical education, continuing medical education, graduate medical education, and postgraduate education, January 1982 to August 2012". We used the MESH search phrase regional anaesthesia (both UK and USA spellings) as it encompass all techniques including daughter keywords local, spinal, epidural, nerve blockade, autonomic, brachial plexus, and cervical plexus. Using the same strategy, the National Library of Medicine and Medline databases were searched to update the list of relevant articles from September 2012 to August 2017. The World Health Organisation International Clinical Trials Registry Platform was also searched using combinations of the following terms: "Regional Anesthesia, Regional Anaesthesia, Anesthesiology, Anaesthesiology, Education, Training, Simulation". Lastly, a grey literature search was performed with the parameters "teaching ultrasound-guided regional anaesthesia to residents/trainee anaesthetists/anesthesiologists".

Together, these articles and research studies provided a body of work of previous and current research avenues in RA education and training. Text in all works was also scrutinised for other suggestions and implications for future research. Individual research topics were then re-written in EPICOT format (Evidence, Population, Intervention, Comparison, Outcome, Timestamp) using editorial guidelines from the British Medical Journal.[16]. This guideline seeks to present research recommendations in a format that emphasises specific research questions arising from available evidence. Both authors independently performed the tasks of reading through articles

and re-writing the research topics in EPICOT format. After merging the list of topics, any differences in wording of the EPICOT statements were jointly discussed to reach consensus. This was performed collaboratively and primarily involved clarification or rephrasing of the statement to reduce ambiguity.

Round One Screening

Three rounds of questionnaires were designed. In Round One, the initial list of EPICOT research topics were e-mailed to participants. A 10-point Likert scale was used to rate each presented topic. Participants were asked to score each topic on its own merits, and not to rate topics against each other. The Likert scale used text anchors against the following numerical scores to assist rating; 1 = Not recommended for further research, 4 = Some value for research, 7 = Important area for research, and 10 = Essential research. Participants could also provide suggestions for additional research topics in free text sections. Participants returned their Round One scores directly to study investigator AC. Aggregate scores from all participants were used to calculate the median score for each topic.

A priori thresholds were predefined to categorise topics. A median score of ≥ 6, and for which $\geq$ 60% of the panel scored ≥ 6, were included for final prioritisation in Round Three. This was a stringent threshold to select the highest ranked topics (scored at least high end of "important", or "essential"); and also only considered to be this ranking by the absolute majority of participants. Topics which scored a median ≤ 3 were excluded from further ranking.

Rounds Two and Three Prioritisation

Topics with median scores between 3 and 6 in Round One were re-ranked in Round Two, along with the additional topics suggested by participants in Round One. To emphasise prioritisation of topics, instructions to participants were changed. Each topic was to be given a single score within a range of scores anchored with explicit text descriptions: 1 to 3 for "lowest research priority", 4 to 7 for "interesting but intermediate in research priority", and 8 to 10 for "essential research priority". Participants were asked select the appropriate priority category, chose a score within that category, and to rank topics in relative importance to each other. Topics which scored a median ≤ 3 were excluded.

Round Three was the final questionnaire and prioritised the topics identified as higher ranked in Round One, that is a median score ≥ 6 by more than 60% of participants. This round used the same instructions and Likert scale as in Round Two. Figure 1 illustrates this Delphi methodology.

In all rounds, participants did not interact, nor were they aware of the identities of other participants. A table summary of the previous round, with the median, interquartile range, and absolute percentage of participants who scored ≥ 6 for all research topics, was provided to all participants. However, no individual scores or comments were identified in these summaries. Only study investigator AC had access to individual scores. Participants were given three weeks to score each round. Reminder e-mails were sent one week prior, and three days after, this deadline.

All scores were entered into a Microsoft Excel spreadsheet (version 2016, Microsoft Corp, Redmond, WA). Descriptive statistics were performed and reported as median scores with 25th to 75th interquartile range (IQR), and as the proportion of all participants who scored 6 or higher for each topic.

Results

Fifty-two e-mail invitations were sent. Thirty-eight participants (73%) accepted the invitation. Thirty-seven returned scores for Round One (97% response). All 38 participants returned scores for Rounds Two and Three (100% response). The 38 participants included 29 authors (76%) of regional anaesthesia education journal articles and regional anaesthesia textbook contributions, 20 training program directors (53%), and 12 were also members of national or international anaesthesia education programs (32%).

In Round One, participants ranked the 74 initially generated topics. Fifty topics reached the threshold of higher priority scores and were included in Round Three. In Round Two, 24 intermediate ranked topics were scored, along with 8 new topics suggested by participants. Based on predefined criteria, no topic was excluded in either Rounds One or Two. A total of 82 topics were thus ranked in order of research priority in Round Three. These results are summarised in Figure 1.

Topics were categorised into seven themes: research on structure and design of a RA training curriculum; the effectiveness of equipment and *in vitro* models in training RA skill sets; assessment of RA knowledge and skills; knowledge translation from practice and lectures to RA performance in a clinical setting; research methodology and protocol design of RA education studies; research on development, retention, and proficiency of RA motor skills; and the role of simulation in RA education.

There were 13 topics ranked as “essential research priority” by participants, defined as median scores of 8 or higher in Round Three. These topics are listed in Table 1. There were 4 topics each on simulation and curriculum, 3 topics on knowledge translation, and 1 topic each on methodology and assessment.

Table 2 includes the next 24 topics scored as a 7, which is equivalent to the highest cohort of intermediate priority topics. Table 3 includes the 13 lowest ranked topics. The supplementary tables re-categorizes all 82 topics into the seven themes of curriculum (Table S1), equipment (Table S2), assessment (Table S3), knowledge translation (Table S4), methodology (Table S5), motor skills (Table S6), and simulation (Table S7).

For all tables, topics are arranged in order of highest to lowest overall median score, and then by order of proportion of participants who scored at least 6 in Round 3.

Discussion

This study summarised the large and diverse body of research activities in regional anaesthesia education. These research activities were re-written as 82 research topics, and scored by a panel of expert participants who ranked these topics in order of importance. Thirteen topics were found to be of essential priority, and resolving these specific questions would advance our current understanding of RA education.

Four of these topics were on the role of simulation. Further evidence is required to inform appropriate learning objectives and competency milestones during simulation training. In turn, deliberate practice is the educational technique that describes repetitive practice using these pre-defined learning outcomes, with structured feedback by expert faculty.[17] While evidence for deliberate practice exists in RA ultrasound-guided needle guidance studies,[18,19] the effectiveness of deliberate practice in RA simulation training was identified as a priority research area. Determining whether simulation training ultimately influences patient outcomes such as improved safety, faster performance, and higher efficacy, versus traditional clinical exposure, were also regarded as priorities. Indeed, a recent systematic review of randomized controlled trials found only one study looked at patient outcomes after simulation training in regional anaesthesia.[6]

There were four curriculum topics ranked as essential. A description of a redesigned RA curriculum,[20] based on a framework for systematic training and assessment of technical skills,[21] has been previously published. Our study found, however, that further work is required to help define the characteristics of an ideal RA curriculum, including what are the core RA skill sets. Evaluation of success of the curriculum was also deemed to be a priority. Many institutions have dedicated RA “block rooms”, but measuring effectiveness of this initiative remains elusive. A

recent article, published after this study commenced, found that surrogate measures of analgesia, pain scores and opioid consumption were reduced after introduction of a block room.[22]

Questions remained about the ability of physicians to maintain RA knowledge and motor skills. This was identified as translation of skill sets between different RA procedures, and whether anesthetists (trainees or consultants) can retain new information learnt at workshops and simulation into clinical practice.

The two remaining essential priority topics were on assessment of the RA procedural skill. This involved defining the minimum competency for each RA task, and to reach consensus on which assessment tools should be used to evaluate competency. A systematic review has recently summarised the available assessment tools for RA procedures.[23]

The strengths of this prioritisation exercise include using a prospective, structured, electronic Delphi technique. Expert regional anesthetists participated in categorising research topics over three iterative rounds of scoring, with an excellent response rate. The panel was international, with a large proportion contributing to the subspecialty as original journal authors and directors of RA training. The de-identified nature of scoring reduces bias from strong personalities influencing the consensus outcomes. Lastly, we pre-defined *a priori* thresholds for defining consensus, an important feature of robust Delphi studies.[24]

We thus believe that the essential priority topics identified in this study are clinically relevant to anaesthetists involved in RA education. For researchers, our results provide guidance on research activities that delivers highest clinical and educational impact. Conversely, we do not imply that research in lower ranked topics is discouraged. As examples, topics in the top 30 are still rated

highly by > 70% of participants and include questions on standardising outcome measures in RA studies, as well as characterising and remediating quality compromising behaviours by novices.

There are several limitations to our study. Participants in this study are active and passionate RA educators and anaesthetists. Nonetheless, the sample size of 38 experts will not be representative of the entire RA research community, nor did we include anaesthesia trainees or public representatives who may harbour different weightings for the research priorities due to their unique perspectives. Even within this small panel, there were divergent opinions on the ranking of each topic, evidenced by relatively wide interquartile ranges. Surveying RA program directors in all RA societies world-wide may not necessarily provide a narrower result: the relative value each participant places on a specific topic will be influenced by their personal experiences and learning environments, and is a possible explanation of the differences in scoring. This subjective bias is minimized, but not fully removed, by imposing a minimum of two rounds of scoring for each topic, and by aggregating scores from all participants.

Each study in the Round One topic generation phase was treated independently when creating the EPICOT statements. This resulted in research topics with similar wording, and potentially could have been condensed. However, a strength of EPICOT is that the generated statements preserves context.[16] For example, the question "standardizing outcome measures in RA education" was ranked differently if related to assessment tools (rank 10), versus patient clinical outcomes (rank 14), and in a simulation context (rank 21). This allows researchers to help refine specific research activity.

The supplementary table reformats all 82 topics based on themes of curriculum, equipment, assessment, knowledge translation, methodology, motor skills and simulation. We caution that these themes are subjective and were categorised *post hoc*, as presented in the supplementary

tables. During the prioritisation phase, participants ranked topics without these thematic labels, and the tables were created only during manuscript preparation. Several topics could be classified under multiple themes. Our results have been presented using thematic organisation, as this may help researchers appreciate important directions and similarities within each theme. A group concept mapping exercise would be a more structured approach to elicit expert opinion on how different but related research topics could be classified.

In conclusion, we present results of a Delphi study designed to summarise, and then rank RA education topics in order of research priority. Experts in RA education, identified through a collaborative process within the ASRA Education Special Interest Group, were invited to participate. The 13 essential topics are diverse in nature, encompassing the role of simulation training, curriculum design, assessment of skills, and retention of skills, in regional anaesthesia. The complete list of 82 topics should be considered by researchers when deciding how best to concentrate their efforts in the advancement of education in our subspecialty.

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Figure Legends

Figure 1: Flow diagram of study, and summary of results at each Delphi round.

Table 1. Topics scored as essential priority, listed in rank order. Only topics scoring 8 or higher included. IQR; interquartile range

Overall Ranking	Topics	Theme	Median (IQR)	Proportion Scored ≥ 6
1	What endpoints/milestones should be achieved on a simulator prior to clinical performance of UGRA?	simulation	8 (7 – 9)	89%
2	Does simulation training show an improvement in clinical outcomes such as improved efficacy, time taken, and less errors?	simulation	8 (6 – 9)	89%
3	Which RA blocks should be considered as a core minimum set for all trainees? Are there benefits in teaching a subset of blocks to competency versus broader exposure to all blocks?	curriculum	8 (7 – 9)	87%
4	Is UGRA knowledge and technical skill generalisable: when does proficiency in one block type transfer to other blocks?	knowledge translation	8 (7 – 8)	87%
5	Does a rotation through a "block room" provide better learning than programs without a block room?	curriculum	8 (6.25 – 8)	82%
6	Is there a minimum number of blocks to attain proficiency for each block or are the skills transferable?	assessment	8 (6.25 – 8)	82%
7	Does simulation training bestow a safety advantage compared to proceeding directly to supervised practice in real patients?	simulation	8 (6 – 9)	82%
8	What criteria should be used to evaluate the success of an UGRA residency training curriculum?	curriculum	8 (6 – 8)	82%
9	What are the necessary components of a formal structured training programme?	curriculum	8 (6 – 8)	82%
10	What should be consensus assessment tools to standardise RA education research?	methodology	8 (6 – 8)	82%
11	What are the most efficacious means for practicing anesthesiologists (consultants) to learn blocks?	knowledge translation	8 (6 – 9)	79%
12	Does deliberate practice in simulation improve RA proficiency?	simulation	8 (5 – 8.75)	71%
13	How can trainees retain proficiency of knowledge and skills learnt after attending focused training (eg. RA rotation, simulation session, workshop)?	knowledge translation	8 (4.25 – 8)	71%

Table 2. Intermediate ranked topics. Only topics scoring 7 included. IQR; interquartile range

Overall Ranking	Topics	Theme	Median (IQR)	Proportion Scored ≥ 6
14	What should be consensus clinical endpoints to standardise RA education study endpoints?	methodology	7.5 (6 – 9)	87%
15	How do you maintain or improve knowledge retention after a one-day workshop?	knowledge translation	7.5 (6 – 8)	79%
16	Does the type and quality of feedback provided by faculty/tutors have an impact on learning outcomes?	simulation	7 (6 – 8)	87%
17	Does short duration courses/workshops result in long term changes in clinical practice?	knowledge translation	7 (6 – 8)	82%
18	What is the best way to establish multicentre collaborative studies in RA education?	methodology	7 (6 – 8)	79%
19	How can cusum methodology be used to track and provide quality assurance of RA clinical performance?	methodology	7 (6 – 8)	79%
20	Does pre-training (ie. Demonstrating competency of discrete tasks before further progression) result in improvement of RA knowledge and technical skills?	knowledge translation	7 (6 – 8)	79%
21	What should be consensus simulation/laboratory endpoints to standardise RA education study endpoints?	methodology	7 (6 – 8)	79%
22	What is the best way to teach sonoanatomy in “difficult” patients (eg. in the morbidly obese, patients with previous surgery)	curriculum	7 (6 – 8)	76%
23	What factors influence the common and recurring quality compromising behaviours observed in novices performing UGRA? What type of training is useful to remedy this behaviour?	motor skills	7 (6 – 8)	76%
24	How regularly does a trainee need to perform a block to be able to perform it independently after residency?	knowledge translation	7 (6 – 8)	76%
25	Is simulation training a cost-effective method of teaching, versus less resource-intensive alternatives?	simulation	7 (6 – 8)	76%
26	How can we best use web based/online resources (viewable content, social media, online assessments, video calls) to deliver	methodology	7 (6 – 8)	76%

	teaching?			
27	What is the optimum mix of lectures, workshops, courses, simulation and direct supervision required to teach RA?	curriculum	7 (5.25 – 8)	74%
28	How do you improve pre-clinical visuo-spatial skill (assuming that visuo-spatial skill is correlated with UGRA motor skills)?	motor skills	7 (5.25 – 8)	74%
29	What forms of instruction or strategies provide the most effective means of improving retention of sono-anatomy?	curriculum	7 (5.25 – 8)	74%
30	Does greater technical ability (proficiency) lead to better outcomes?	motor skills	7 (5 – 8)	71%
31	How do you improve poor coordination and fine motor control prior to clinical exposure?	motor skills	7 (5 – 8)	71%
32	Does pre-procedural knowledge or awareness of critical errors made by trainees, lead to a reduction in clinical errors by trainees?	knowledge translation	7 (5 – 8)	71%
33	Which tasks in UGRA require more resources, effort, and practice to gain competency?	methodology	7 (5 – 8)	71%
34	What are the factors promoting, and inhibiting, access to RA training?	curriculum	7 (5 – 8)	66%
35	Is simulation training more effective in some areas of RA education (eg. Knowledge retention versus technical skills) than in other areas?	simulation	7 (5 – 8)	63%
36	In resource poor countries, what is the best combination of textbooks, accessible online modules and videos, telemedicine, and live model scanning, to deliver a RA curriculum?	curriculum	7 (4 – 8)	63%
37	What are the contributing factors to the practice and impediment of trainees performing regional anesthesia after residency training?	knowledge translation	7 (4 – 8)	58%

Table 3. Lowest ranked topics. Topics scoring 5 or less included. IQR; interquartile range

Overall Ranking	Topics	Theme	Median (IQR)	Proportion Scored ≥ 6
69	Which blocks, or when, is neurostimulation best used to assist location of the needle tip?	equipment	5 (2.25 – 6)	47%
70	Does simulation training show an improvement in non-technical attributes such as communication, team work, professionalism and resource management?	simulation	5 (3 – 7)	47%
71	What is the best way to teach neuraxial sonoanatomy?	curriculum	5 (3.25 – 7)	47%
72	What is the best way to teach ergonomic principles and practices necessary for performing RA blocks?	curriculum	5 (3 – 7)	47%
73	In what situations is the learning outcomes from self-directed teaching no different from deliberate feedback?	assessment	5 (4 – 7)	45%
74	Does electromagnetic guidance modalities (radio-frequency tracking, needle magnetic currents) assist in needle tip and shaft localisation in UGRA?	equipment	5 (3 – 6.75)	42%
75	Which of the high fidelity cadaver models (ie. Thiel, fresh frozen, Batson, formalin) offer the best compromise between face validity, construct validity, availability, and cost?	equipment	5 (4 – 7)	42%
76	Which of the low fidelity phantoms (ie. gelatine, agar, tofu) offer the best compromise between face validity, construct validity, availability, and cost?	equipment	5 (4 – 7)	42%
77	Is there a role for a progression from low fidelity to high fidelity UGRA phantoms in teaching regional anaesthesia?	equipment	5 (3 – 7)	42%
78	Does 3D/4D ultrasound assist needle tip guidance in UGRA?	equipment	5 (2.25 – 6.75)	34%
79	Should we screen for technical and non-technical qualities predisposing to procedural skills proficiency, when selecting residents during the employment process?	assessment	4 (2 – 7.75)	39%
80	Which of the meat-based models (eg. pork, beef, turkey) offer the best compromise between face validity, construct validity, availability, and cost?	equipment	4 (3 -6)	32%

81	Do rigid needle trajectory guides (clip on accessory to transducers) assist in needle tip and shaft localisation in UGRA?	equipment	4 (3 – 6)	29%
82	Does robotic assistance aid needle tip positioning for RA?	equipment	3 (2 – 5.75)	26%

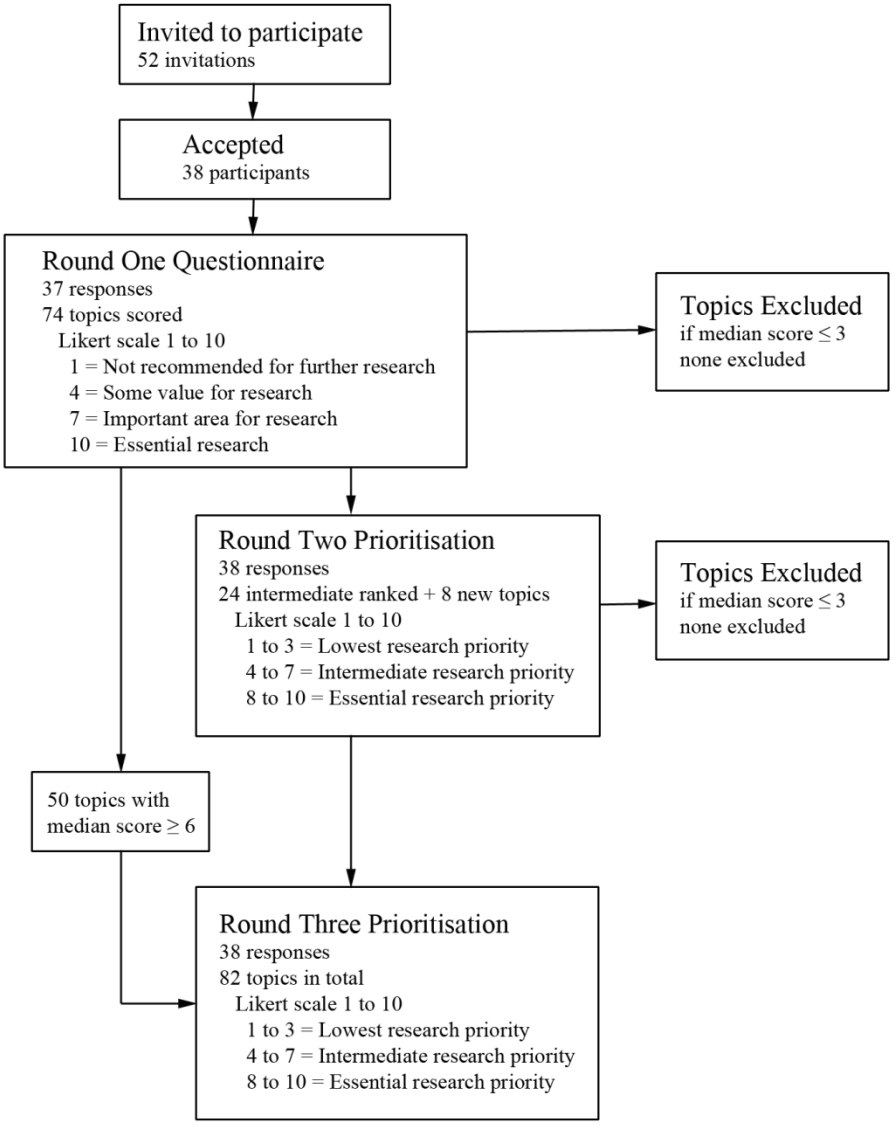

Figure 1: Flow diagram of study, and summary of results at each Delphi round.

Supplemental Tables.

Table S1. Curriculum themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
3	Which RA blocks should be considered as a core minimum set for all trainees? Are there benefits in teaching a subset of blocks to competency versus broader exposure to all blocks?	8 (7 – 9)	87%
5	Does a rotation through a "block room" provide better learning than programs without a block room?	8 (6.25 – 8)	82%
8	What criteria should be used to evaluate the success of an UGRA residency training curriculum?	8 (6 – 8)	82%
9	What are the necessary components of a formal structured training programme?	8 (6 – 8)	82%
22	What is the best way to teach sonoanatomy in "difficult" patients (eg. in the morbidly obese, patients with previous surgery)	7 (6 – 8)	76%
27	What is the optimum mix of lectures, workshops, courses, simulation and direct supervision required to teach RA?	7 (5.25 – 8)	74%
29	What forms of instruction or strategies provide the most effective means of improving retention of sono-anatomy?	7 (5.25 – 8)	74%
34	What are the factors promoting, and inhibiting, access to RA training?	7 (5 – 8)	66%
36	In resource poor countries, what is the best combination of textbooks, accessible online modules and videos, telemedicine, and live model scanning, to deliver a RA curriculum?	7 (4 – 8)	63%
39	What standards of teaching should we expect faculty/tutors to attain? Should we assess the assessors for quality of teaching?	6.5 (5 – 8)	71%
41	Do 'teach the teacher' courses improve the ability to provide feedback and better assessment of RA procedural skills?	6.5 (4 – 7.75)	66%
49	Does provision of an "image bank" of sonoanatomy provide better learning than live model scanning?	6 (3.25 – 7)	63%
53	Does competency-based training improve patient outcomes compared to simulation-based training?	6 (5 – 8)	63%
56	What teaching tools or methodologies can be used to improve comprehension of sono-anatomy?	6 (5 – 8)	61%
61	How can we deliver teaching and support through the use of telemedicine technology? Can it be used as a follow-up for live-hands on sessions?	6 (5 – 7)	58%
71	What is the best way to teach neuraxial sonoanatomy?	5 (3.25 – 7)	47%
72	What is the best way to teach ergonomic principles and practices necessary for performing RA blocks?	5 (3 – 7)	47%

IQR; interquartile range

Table S2. Equipment themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
48	Which areas of teaching show no difference in learning outcome using cheaper low fidelity models, versus expensive high fidelity models? In what situations does higher fidelity models confer an advantage for learning?	6 (5 – 8)	63%
60	What are the roles of lower fidelity, versus higher fidelity, simulation practice in UGRA? Are higher fidelity models most appropriate when teaching difficult/complex blocks or when teaching advanced skills?	6 (5 – 8)	58%
62	Which models offer the best compromise between face validity, construct validity, availability, and cost, for ultrasound/fluoroscopy guided neuraxial/para-axial blocks?	6 (3 – 7)	55%
64	How does the use of eye tracking technology help in teaching RA?	6 (4 – 7)	55%
67	Can the use of hand motion technology help in teaching RA?	5.5 (4.25 – 7)	50%
68	Which echogenic needle technology provides the best visibility for UGRA procedures?	5.5 (3.25 – 7)	50%
69	Which blocks, or when, is neurostimulation best used to assist location of the needle tip?	5 (2.25 – 6)	47%
74	Does electromagnetic guidance modalities (radio-frequency tracking, needle magnetic currents) assist in needle tip and shaft localisation in UGRA?	5 (3 – 6.75)	42%
75	Which of the high fidelity cadaver models (ie. Thiel, fresh frozen, Batson, formalin) offer the best compromise between face validity, construct validity, availability, and cost?	5 (4 – 7)	42%
76	Which of the low fidelity phantoms (ie. gelatine, agar, tofu) offer the best compromise between face validity, construct validity, availability, and cost?	5 (4 – 7)	42%
77	Is there a role for a progression from low fidelity to high fidelity UGRA phantoms in teaching regional anaesthesia?	5 (3 – 7)	42%
78	Does 3D/4D ultrasound assist needle tip guidance in UGRA?	5 (2.25 – 6.75)	34%
80	Which of the meat-based models (eg. pork, beef, turkey) offer the best compromise between face validity, construct validity, availability, and cost?	4 (3 – 6)	32%
81	Do rigid needle trajectory guides (clip on accessory to transducers) assist in needle tip and shaft localisation in UGRA?	4 (3 – 6)	29%
82	Does robotic assistance aid needle tip positioning for	3 (2 –	26%

	RA?	5.75)	

IQR; interquartile range

Table S3. Assessment themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
6	Is there a minimum number of blocks to attain proficiency for each block or are the skills transferable?	8 (6.25 – 8)	82%
50	How do you identify the trainee with poor coordination and fine motor control?	6 (5 – 7)	63%
51	How do we best evaluate the non-technical skills of regional anaesthesia?	6 (5 – 7)	63%
52	Does using a didactic step-by-step checklist of sonoanatomical landmarks during scanning help novices learn sonoanatomy?	6 (4 – 7)	63%
55	What characteristics or attitudes do successful and unsuccessful UGRA performers possess?	6 (4 – 7.75)	61%
59	What is the role of the regional anaesthetists' teaching skill on residents performance?	6 (5 – 7)	58%
65	What characteristics or attitudes do effective teachers of UGRA possess?	6 (5 – 7)	55%
66	What is the role of coaches on improving the teachers of regional anaesthesia?	5.5 (3.25 – 7.75)	50%
73	In what situations is the learning outcomes from self-directed teaching no different from deliberate feedback?	5 (4 – 7)	45%
79	Should we screen for technical and non-technical qualities predisposing to procedural skills proficiency, when selecting residents during the employment process?	4 (2 – 7.75)	39%

IQR; interquartile range

Table S4. Knowledge translation themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
4	Is UGRA knowledge and technical skill generalisable: when does proficiency in one block type transfer to other blocks?	8 (7 – 8)	87%
11	What are the most efficacious means for practicing anesthesiologists (consultants) to learn blocks?	8 (6 – 9)	79%
13	How can trainees retain proficiency of knowledge and skills learnt after attending focused training (eg. RA rotation, simulation session, workshop)?	8 (4.25 – 8)	71%
15	How do you maintain or improve knowledge retention after a one-day workshop?	7.5 (6 – 8)	79%
17	Does short duration courses/workshops result in long term changes in clinical practice?	7 (6 – 8)	82%
20	Does pre-training (ie. Demonstrating competency of discrete tasks before further progression) result in improvement of RA knowledge and technical skills?	7 (6 – 8)	79%
24	How regularly does a trainee need to perform a block to be able to perform it independently after residency?	7 (6 – 8)	76%
32	Does pre-procedural knowledge or awareness of critical errors made by trainees, lead to a reduction in clinical errors by trainees?	7 (5 – 8)	71%
37	What are the contributing factors to the practice and impediment of trainees performing regional anaesthesia after residency training?	7 (4 – 8)	58%
57	What factors contribute to variability in understanding or identifying sono-anatomy?	6 (5 – 7)	61%

IQR; interquartile range

Table S5. Methodology themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
10	What should be consensus assessment tools to standardise RA education research?	8 (6 – 8)	82%
14	What should be consensus clinical endpoints to standardise RA education study endpoints?	7.5 (6 – 9)	87%
18	What is the best way to establish multicentre collaborative studies in RA education?	7 (6 – 8)	79%
19	How can cusum methodology be used to track and provide quality assurance of RA clinical performance?	7 (6 – 8)	79%
21	What should be consensus simulation/laboratory endpoints to standardise RA education study endpoints?	7 (6 – 8)	79%
26	How can we best use web based/online resources (viewable content, social media, online assessments, video calls) to deliver teaching?	7 (6 – 8)	76%
33	Which tasks in UGRA require more resources, effort, and practice to gain competency?	7 (5 – 8)	71%
43	What are the influences of the wide inter-individual learning curve in RA? Are any of these factors amenable to intervention?	6 (5 – 8)	68%
45	Should hierarchical task analysis be used to deconstruct and analyse each RA block for error rates?	6 (5 – 7)	63%
46	Would determining the learning style of trainees be helpful to assist in matching trainees to how best they learn content and type of content delivery?	6 (5 – 7.75)	63%
58	What is the best way to teach non-technical skills in RA, for example communication, professionalism, and resource management?	6 (4 – 7)	58%

IQR; interquartile range

Table S6. Motor skills themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
23	What factors influence the common and recurring quality compromising behaviours observed in novices performing UGRA? What type of training is useful to remedy this behaviour?	7 (6 – 8)	76%
28	How do you improve pre-clinical visuo-spatial skill (assuming that visuo-spatial skill is correlated with UGRA motor skills)?	7 (5.25 – 8)	74%
30	Does greater technical ability (proficiency) lead to better outcomes?	7 (5 – 8)	71%
31	How do you improve poor coordination and fine motor control prior to clinical exposure?	7 (5 – 8)	71%
42	Does a didactic step-by-step checklist, or proscribed method of transducer/needling technique, improve the quality of needle guidance?	6.5 (4.25 – 7)	58%
44	What is the importance of psychometric ability (visuospatial and psychomotor ability) on UGRA skills?	6 (5 – 7.75)	66%
47	What is the best way to teach out-of-plane needle approaches?	6 (5 – 8)	63%
54	What is the best way to teach needle guidance for neuraxial procedures?	6 (5 – 7)	61%

IQR; interquartile range

Table S7. Simulation themed topics, listed by rank order

Ranking	Topics	Median (IQR)	Proportion Scored ≥ 6
1	What endpoints/milestones should be achieved on a simulator prior to clinical performance of UGRA?	8 (7 – 9)	89%
2	Does simulation training show an improvement in clinical outcomes such as improved efficacy, time taken, and less errors?	8 (6 – 9)	89%
7	Does simulation training bestow a safety advantage compared to proceeding directly to supervised practice in real patients?	8 (6 – 9)	82%
12	Does deliberate practice in simulation improve RA proficiency?	8 (5 – 8.75)	71%
16	Does the type and quality of feedback provided by faculty/tutors have an impact on learning outcomes?	7 (6 – 8)	87%
25	Is simulation training a cost-effective method of teaching, versus less resource-intensive alternatives?	7 (6 – 8)	76%
35	Is simulation training more effective in some areas of RA education (eg. Knowledge retention versus technical skills) than in other areas?	7 (5 – 8)	63%
38	What is the best way to use augmented or virtual reality devices in RA simulation training?	6.5 (5.25 – 8)	74%
40	What is the best way to debrief using video recordings of trainee performance during simulation training?	6.5 (5 – 8)	68%
63	When is the best time during training to introduce simulation to novices learning RA?	6 (4 – 8)	55%
70	Does simulation training show an improvement in non-technical attributes such as communication, team work, professionalism and resource management?	5 (3 – 7)	47%

IQR; interquartile range

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Done
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Pg1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Pg2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pg4
Objectives	3	State specific objectives, including any prespecified hypotheses	Pg5
Methods			
Study design	4	Present key elements of study design early in the paper	Pg5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Pg6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Pg 6, 8, 9
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pg 8,9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Pg8,9
Bias	9	Describe any efforts to address potential sources of bias	Pg9
Study size	10	Explain how the study size was arrived at	Pg6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Pg9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Pg9
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	N/A
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	N/A

Results			**Done**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Pg11
		(b) Give reasons for non-participation at each stage	Pg11
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	N/A
		(b) Indicate number of participants with missing data for each variable of interest	Pg11
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Pg11
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Pg11
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	N/A
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Pg11
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	Pg13,14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Pg15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pg15,16
Generalisability	21	Discuss the generalisability (external validity) of the study results	Pg 15,16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Pg3

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.