ORIGINAL ARTICLE

Ultrasound-Guided Regional Anesthesia Simulation Training
A Systematic Review

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Background and Objectives: Ultrasound-guided regional anesthesia (UGRA) has become the criterion standard of regional anesthesia practice. Ultrasound-guided regional anesthesia teaching programs often use simulation, and guidelines have been published to help guide URGA education. This systematic review aimed to examine the effectiveness of simulation-based education for the acquisition and maintenance of competence in UGRA.

Methods: Studies identified in MEDLINE, EMBASE, CINAHL, Cochrane Central Register of Controlled Trials, and ERIC were included if they assessed simulation-based UGRA teaching with outcomes measured at Kirkpatrick level 2 (knowledge and skills), 3 (transfer of learning to the workplace), or 4 (patient outcomes). Two authors independently reviewed all identified references for eligibility, abstracted data, and appraised quality.

Results: After screening 176 citations and 45 full-text articles, 12 studies were included. Simulation-enhanced training improved knowledge acquisition (Kirkpatrick level 2) when compared with nonsimulation training. Seven studies measuring skill acquisition (Kirkpatrick level 2) found that simulation-enhanced UGRA training was significantly more effective than alternative teaching methods or no intervention. One study measuring transfer of learning into the clinical setting (Kirkpatrick level 3) found no difference between simulation-enhanced UGRA training and non–simulation-based training. However, this study was discontinued early because of technical challenges. Two studies examined patient outcomes (Kirkpatrick level 4), and one of these found that simulation-based UGRA training improved patient outcomes compared with didactic teaching.

Conclusions: Ultrasound-guided regional anesthesia knowledge and skills significantly improved with simulation training. The acquired UGRA skills may be transferred to the clinical setting; however, further studies are required to confirm these changes translate to improved patient outcomes.

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Ultrasound-guided regional anesthesia (UGRA) has evolved rapidly during the last 2 decades. Since Kapral first described the use of real-time UGRA in 1994, UGRA has gained international recognition and has been shown to be associated with clinically relevant advantages such as increased success rate, reduced onset time, moderately prolonged duration, reduced need for local anesthetics, lower costs, and reduced risk of complications.[1,2]

Health care providers need to be trained in order to incorporate new UGRA procedures into routine clinical practice. Many specialized programs and workshops have been designed to teach UGRA skills, and guidelines have been published to offer assistance in teaching these skills.[3] Various teaching modalities may be used, from didactic to simulation techniques, ranging from simple low-fidelity part-task training models to highly sophisticated virtual-reality models.

Recent systematic reviews show that simulation-based training in health care is generally associated with moderate to large effects for educational outcomes when compared with no intervention and small to moderate effects when compared with nonsimulation instructional approaches, such as lectures.[4] Evidence-based education aims to promote educational techniques based on significant and reliable findings derived from experiments. It shares with evidence-based medicine the aim of informing best practices by relying on the most up-to-date available evidence, gained from the scientific method.

In 2013, Nix et al[5] published a scoping review, which summarized the limited evidence regarding how best to teach UGRA. They identified 3 themes, including motor skills, sonoanatomy, and UGRA program evaluation. However, a systematic assessment of the evidence has yet been done to determine the effectiveness of simulation-based education for acquisition and maintenance of competence in UGRA.[6,7]

We aimed to summarize the existing literature on simulation-based UGRA education to investigate the effectiveness of simulation-based UGRA education. The results will help optimize educational programs in training and maintaining competency for UGRA, ultimately benefiting patient care.

METHODS

Protocol

This review was planned and conducted according to AMSTAR (A Measurement Tool to Assess Systematic Reviews) standards[8] and reported in adherence to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) checklist.[9] The protocol (CRD42015029896) was registered with PROSPERO (International Prospective Register of Systematic Reviews).

A review protocol and a search strategy following PRISMA-P guidelines were compiled and revised by the investigators (A.C.T., S.B.), who together have expertise in systematic review methodology, medical education, and clinical care.

Eligibility Criteria

We included only studies that were randomized controlled trials (RCTs), including, quasi-, cluster, and crossover RCTs that compared the effectiveness of simulation-based education with UGRA versus no education or alternative type of education for health care providers. We defined simulation as an "educational tool or device with which the learner physically interacts to mimic an aspect of clinical care. Such tools included robotic and static mannequins, partial task trainers, cadavers, live animals or animal parts, and computer-based virtual reality simulators."[10] Eligible participants included health care providers from any discipline, including staff physicians, residents, medical students, anesthesia assistants, and anesthesia registered nurses at any stage of training or practice, for both initial and retraining. We elected to focus on UGRA–sonographic Doppler, imaging 2-dimensional ultrasound, and dynamic and static use of the ultrasound versus RA without ultrasound guidance. This is because the use of ultrasound for regional blocks is now the criterion standard of practice and has the potential to improve success rates and patient safety. In addition, practicing ultrasound-guided regional blocks without adequate training raises the danger of malpractice and subsequent impaired outcomes.[1,11]

We report in our systematic review all outcomes reported in included studies, assessed in either simulated or clinical settings. Any timing for testing learning was included, such as immediate (<24 hours) and delayed (after 24 hours) outcomes.

Outcomes were classified using a modified Kirkpatrick model at 4 levels.[12] Studies were included if they measured identifiable UGRA skills at level(s) 2, 3, and/or 4, including performance of knowledge and skills in an immediate and delayed test (ie, simulated setting), behaviors (ie, skills in real-life settings), and effects on patient outcome (ie, successful block). We excluded articles measuring Kirkpatrick level 1 (ie, learners' reaction to learning and self-assessment outcomes), because reaction to learning has limited impact on learning, and evidence shows that self-assessment is not accurate for health care professionals.[13] Only English-language publications were included because of feasibility of the reviewing process.

In the original Kirkpatrick framework,[12] learning outcomes resulting from educational interventions in health care are classified into 4 levels:

- level 1—reaction: measures how learners perceive the educational intervention;
- level 2—learning: measures acquisition of skills/knowledge/attitudes in a nonclinical setting (ie, simulation laboratories);
- level 3—behavior: measures learners behavioral changes in the professional setting (ie, transfer of learning to the clinical setting);
- level 4—results: measures the effect of learners' actions (ie, improved patient outcomes).

Study Design

Search Strategy and Information Sources

The literature search was performed by an experienced librarian in close collaboration with the rest of the research team from inception to November 30, 2015. It was then peer reviewed by another librarian using the PRESS checklist. All studies were performed in the field of teaching and learning motor skills of UGRA, without year or language restrictions, with 1 or more of the terms listed in Appendix 1, Supplemental Digital Content 1, http://links.lww.com/AAP/A211. Databases used included MEDLINE, EMBASE, CINAHL, Cochrane Central Register of Controlled Trials, and ERIC. The reference list of included studied were also scanned for eligibility.

Study Selection

All titles and abstracts were screened for eligibility by independent reviewers in duplicate using a previously pilot-tested template (A.A.A., X.X.C., and V.T.). Full-text copies of all studies that appeared to meet the inclusion criteria were then obtained for further assessment. Full-text screening applying all inclusion and exclusion criteria was then performed by independent reviewers in duplicate (A.A.A., X.X.C., and V.T.). Disagreements on eligibility were resolved by discussion and agreement with guidance of a third author (A.A.A.).

Data Items and Abstraction

Using a predefined data extraction form with inclusion and exclusion criteria, pairs of authors (A.A.A., S.C.T., X.X.C., and V.T.) extracted data from all included articles independently and in duplicate. Disagreements were resolved by consensus and with a third reviewer (A.A.A.) if needed. The data extraction form collected general article information, demographics of learners, description of the intervention and the control, and data on outcome measures and quality.

Risk of Bias in Individual Studies

The reviewers (S.C.T., X.X.C., and V.T.) independently and in duplicate assessed each included study for risk of bias using the Cochrane Collaboration's tool[14] for RCTs. To assess the quality of the medical education component, the Medical Education Research Study Quality Instrument (MERSQI)[15] was used. Disagreements were resolved by consensus and with a third reviewer (A.A.A.) if needed.

Synthesis

A meta-analysis was not performed because of heterogeneity of study design and outcome measures; instead, a narrative summary was conducted.

RESULTS

Study Selection

The literature search yielded 176 unique citations, of which 45 were potentially relevant, and the full text was reviewed (Fig. 1). Subsequently, 12 studies met the inclusion criteria and were included in this systematic review.[16–27]

Study Characteristics

Included studies were published between 2008 and 2015. Most studies were conducted in North America. Details on included study characteristics, participants, interventions, methods, and results are presented in Tables 1 and 2.

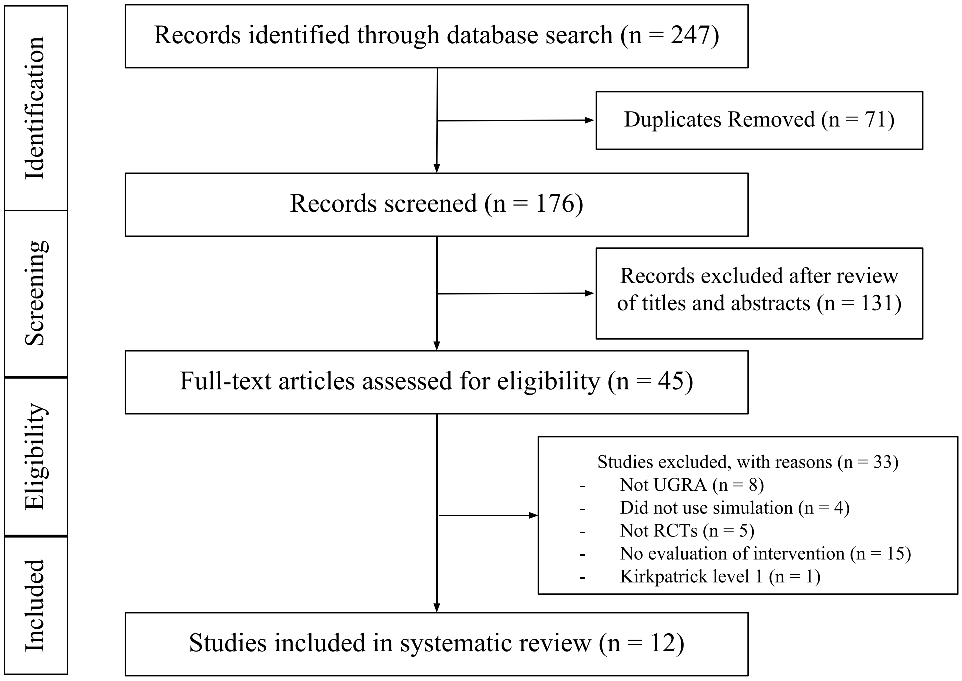

FIGURE 1. Trial flow diagram.

Training Characteristics

Eleven studies used a combination of didactic and simulation training approaches in teaching UGRA principles,[16–20,22–27] and 1 study used only simulation to evaluate the effect of a needle guidance system on UGRA skills of novices.[21]

Evaluation of Outcomes and Assessment Tools

Using the Kirkpatrick framework, several outcome levels can be combined into a single study. One study investigated Kirkpatrick levels 2, 3, and 4 by measuring the knowledge and skills (level 2), performance in the workplace (level 3), and patient outcome (level 4).[23] A second study also investigated Kirkpatrick levels 2 and 4.[22] The remaining 10 studies investigated Kirkpatrick level 2 only.[16–21,24–27]

Risk of Bias

Overall, the studies included in this systematic review appear to be at a moderate or low risk of bias. However, 2 domains remained high risk, specifically with regard to performance bias and attrition bias. Eight studies were found to be high risk in blinding participants and personnel (performance bias).[17,20–23,25–27] Five studies were found to be high risk for blinding of outcome assessment (detection bias).[16,21,22,25,27] Also, 4 studies were found to be high risk in incomplete outcome data (attrition bias).[17,22,23,25] Figure 2 shows a risk of bias summary for the 12 included studies using the Effective Practice and Organisation of Care (EPOC) tool.

Effects of Intervention

Among the studies, simulation-based UGRA was evaluated in comparison to a variety of alternative teaching methods, including didactic as well as non–simulation-based interventions (Table 3).[16–27]

All included studies measured knowledge and/or skill acquisition. In terms of UGRA knowledge acquisition (Kirkpatrick level 2), 5 studies found that simulation-enhanced training improved sonoanatomy and written test scores compared with nonsimulation training.[17,18,25–27]

Among the 11 studies that measured UGRA skills acquisition (Kirkpatrick level 2), 8 studies found increased effectiveness of simulation-enhanced UGRA training, including when compared with didactic teaching alone (ie, improved success of blocks: control vs simulation training group, 51% vs 64%, $P < 0.001$).[16–22,24] One study did note that while an electronic tutorial in addition to hands-on ultrasound improved accuracy of anatomical identification, it prolonged time to identification (1053 ± 244 vs 740 ± 244 seconds, $P = 0.001$).[26] Similarly, another study found that video teaching followed by simulation improved knowledge but failed to improve hands-on performance of ultrasound scanning to localize the nerve (skills).[27]

In regard to the transfer of learning to the workplace (Kirkpatrick level 3), O'Sullivan et al[23] found no significant difference in clinical performance between the simulation and control groups, but their study was aborted prematurely after an interim analysis because "the functionality of the available simulator was insufficient to meet [their] training requirements."[23]

Two studies evaluated patient outcomes (Kirkpatrick level 4). One of these studies found that simulation-enhanced UGRA improved success of the block when compared with control (64% vs 51.3%, $P < 0.016$).[22] The second study from O'Sullivan et al[23] did not analyze any patient outcome data because all participants from both the simulation and the control groups failed to perform the block independently. As mentioned previously, the authors believed that this was due to poor functionality of the simulator.[23]

Study Quality

The MERSQI[15] was used to assess the medical education research study quality, and data are summarized in Table 2. The number of participants ranged from 9 to 50 with a median of 30. Two of the studies were multi-institutional.[23,27] Eleven of 12 studies used objective assessment measures,[16–21,23–27] and 7 of 12 had response rates of at least 75%.[17,21,23–27] The mean MERSQI (maximum 18

TABLE 1. Key Features of Studies Included in Systematic Review of UGRA Simulation Training

Study Characteristic	Level	No. of Studies (No. of Participants)
All studies		
Group allocation	Randomized	12 (361)
Participant	Medical students	2 (56)
	Physicians in postgraduate training specialty (anesthesia)	3 (49)
	Physicians in practice, specialty (anesthesia)	1 (36)
	Nurses in practice	1 (33)
	Nursing students	0
	Emergency medical technicians or students	0
	Other (volunteers)	1 (35)
	Unclear	1 (39)
	Mixed (anesthesia resident, fellow, and staff)	3 (113)
Type of UGRA intervention	UGRA for peripheral nerve block either single shot or continuous	11 (311)
	Ultrasound-guided spinal	1 (50)
	Ultrasound-guided epidural	0
	Ultrasound-guided combined spinal epidural	0
Type of simulation used for training	Low-fidelity models	5 (140)
	High-fidelity models	1 (39)
	Virtual-reality models	1 (26)
	Virtual-reality and Life models	3 (113)
	Virtual-reality models, Life models, and cadavers	2 (43)
Outcomes	Knowledge	10 (318), 1 (33),* 1 (10)†
	Skill: time	3 (75), 1 (35)‡
	Skill: process	1 (26), 1 (33),* 1 (30)§
	Skill: product	1 (30)§
	Behavior: time	1 (35),‡ 1 (10)†
	Behavior: process	0
	Patient effects	1 (30),§ 1(10)†

*Involves both knowledge and skill process outcomes.
†Involves knowledge, behavior time, and patient effect outcomes.
‡Involves skill time and behavior time outcomes.
§Involves skill process, skill product, and patient effect outcomes.

points) study quality score was 13.9 (SD, 1.8). Appendix 2, Supplemental Digital Content 2, http://links.lww.com/AAP/A212, summarizes MERSQI scores of the individual studies.

DISCUSSION

Our systematic review of RCTs in the current literature suggests that simulation-enhanced UGRA teaching improves knowledge acquisition with this specific skill set. With regard to skill acquisition, most studies show that there is a benefit to incorporating simulation training. However, the specific modality to be utilized or combination thereof remains to be ascertained.

The findings of this review show evidence that simulation-enhanced learning is effective for acquiring new knowledge and skills. A systematic review and meta-analysis evaluating the benefits of technology-enhanced simulation in emergency medicine also found a significant improvement in knowledge and skills acquisition when compared with no intervention.[10] The current evidence suggests a shortened learning curve when acquiring a new skill by learning with simulation.[5] Our results support simulation-based education to learn UGRA.

Current recommendations for education and training in UGRA are based mainly on expert opinion and clinical experience.[3] By reviewing the current RCTs and compiling their data, our review and subsequent analysis strengthen the argument for applying simulation-enhanced teaching modalities to current practice. A specific recommendation cannot be made with regard to the type of simulation modality to be utilized. However, when deciding on the teaching curriculum, it is important to consider elements such as cost, availability of expert instructors, and time constraints. The effectiveness and success of future curricula, teaching modules, and policies will be dependent on the proposed methods of evaluation and teaching not only for the learners, but also for the individuals involved with their evaluation (ie, staff). Incorporating simulation-enhanced training with UGRA will increase the likelihood of knowledge and motor-skill acquisition, thus optimizing education time and hopefully improving block success in the clinical setting.

A major strength of our review is that only RCTs were included in the study. Also, these trials were all conducted since 2008, making their findings more applicable to clinical practice and teaching today. Although some evidence exists about the positive impact of UGRA simulation teaching on increased block success in the clinical environment, more studies are needed with a greater number of learners and wider range of regional anesthesia techniques. In order to do so, additional RCTs comparing head-to-head simulation teaching in regional anesthesia, with possibly different instructional design, need to be completed.

TABLE 2. Quality of Studies Included (MERSQI)

Scale Item	Subscale (Points if Present)	No. (%) Present
Study design (maximum 3)	1 Group pre-post (1.5)	12 (100)
	Observational 2 group (2)	
	Randomized 2 group (3)	
Sampling: no. of institutions (maximum 1.5)	1 (0.5)	10 (83)
	2 (1)	2 (17)
	>2 (1.5)	
Sampling: follow-up (maximum 1.5)	<50% or not reported (0.5)	4 (34)
	50–74% (1)	1 (8)
	≥75% (1.5)	7 (58)
Type of data: outcome assessment (maximum 3)	Subjective (1)	1 (8)
	Objective (3)	11 (92)
Validity evidence (maximum 3)	Content (1)	11 (92)
	Internal structure (1)	8 (67)
	Relations to other variables (1)	6 (50)
Data analysis: appropriate (maximum 1)	Appropriate (1)	12 (100)
Data analysis: sophistication (maximum 2)	Descriptive (1)	5 (42)
	Beyond descriptive analysis (2)	7 (58)
Highest outcome type (maximum 3)	Knowledge, skills (1.5)	12 (100)
	Behaviors (2)	2 (17)
	Patient/health care outcomes (3)	2 (17)

The mean score on the MERSQI was 13.9 (SD, 1.8), and median score was 14.5 (range, 10.0–16.5).

Limitations

A few limitations exist that are intrinsic to the studies included in this review. Of note, most of the studies had only a small sample size, with the largest study involving only 50 participants.[25] This is possibly related to the labor-intensive nature of designing studies involving simulation-based education. Simulation-based studies usually target a limited pool of potential participants (eg, residents) who need to voluntarily participate, and these studies involve often multistep assessments and active attendance of subjects in teaching sessions. Also, higher-impact studies involve patients, adding further challenges. In one of the included studies,[22] 10 of the original 30 recruited subjects were excluded because of an inability to complete all tasks required by the study. Challenges may also arise from the technological aspect involved in using simulators.[16–27] One study was forced to terminate early because of deficiencies with the functionality of the simulator itself to prevent adequate teaching.[23]

The type of participants recruited by the studies in this systematic review also ranged greatly in backgrounds, from medical students to practicing anesthesiologists, making the comparability and generalizability of results challenging. Similarly, although broad categories within the Kirkpatrick framework translated in between studies (ie, knowledge assessment using sonoanatomy testing), the specific methods of evaluation varied greatly between each study.

Feedback is an essential element of simulation training.[5,28,29] Unfortunately, only one of the included studies in our review evaluated this important component.[24] We were therefore limited in our ability to gain further insight into the optimal combination of timing and type of feedback to be utilized with simulation-enhanced learning and UGRA. Another limitation of this systematic review relates to the small number of RCTs on this specific topic. It was therefore impossible to draw definitive conclusions with regard to learner behavior and patient outcome linked to specific simulation modality.

Direction for Future Research

Future studies should be of larger sample size. One of the solutions to isolated small sample size studies may be to develop a UGRA collaborative network of centers that will allow designing multicenter studies of adequate power. Before any future large studies, investigators should carefully consider conducting small-scale pilot feasibility studies to avoid early dropout of participants. As noted in previous paragraphs, the current literature examining the teaching of UGRA is heterogeneous with regard to several aspects of the studies such as learners' population, simulation techniques, instructional design, and assessment tools. Future research, potentially via the suggested collaborative network previously mentioned, might consider prioritizing research questions that are clinically relevant. They could also identify reliable and valid assessment tools that will allow comparison of learning methods effectiveness. The UGRA community may consider identifying "agreed standardized sets of outcomes, known as 'core outcome sets,'" as per the COMET initiative (http://www.comet-initiative.org/). These outcomes would be the minimum set of outcome measures required to be included in any UGRA simulation study and would lead to more homogeneous and comparable studies for future systematic reviews. In addition, given the importance of feedback in simulation training, future research may benefit from examining the optimal type and "dose" of feedback, as well as the optimal balance between practice and feedback in UGRA simulation training.

Future research in UGRA should target higher Kirkpatrick levels (≥3). None of the studies included in this review investigated the cost-effectiveness of UGRA training, that is, the highest Kirkpatrick level 5. All studies (n = 12) measured outcomes related to knowledge or skill acquisition on a simulation model (Kirkpatrick level 2); only 1 reached skill assessment at the clinical setting (Kirkpatrick level 3). Only 2 studies measured changes in patient outcomes (Kirkpatrick level 4)[22,23] of which one was

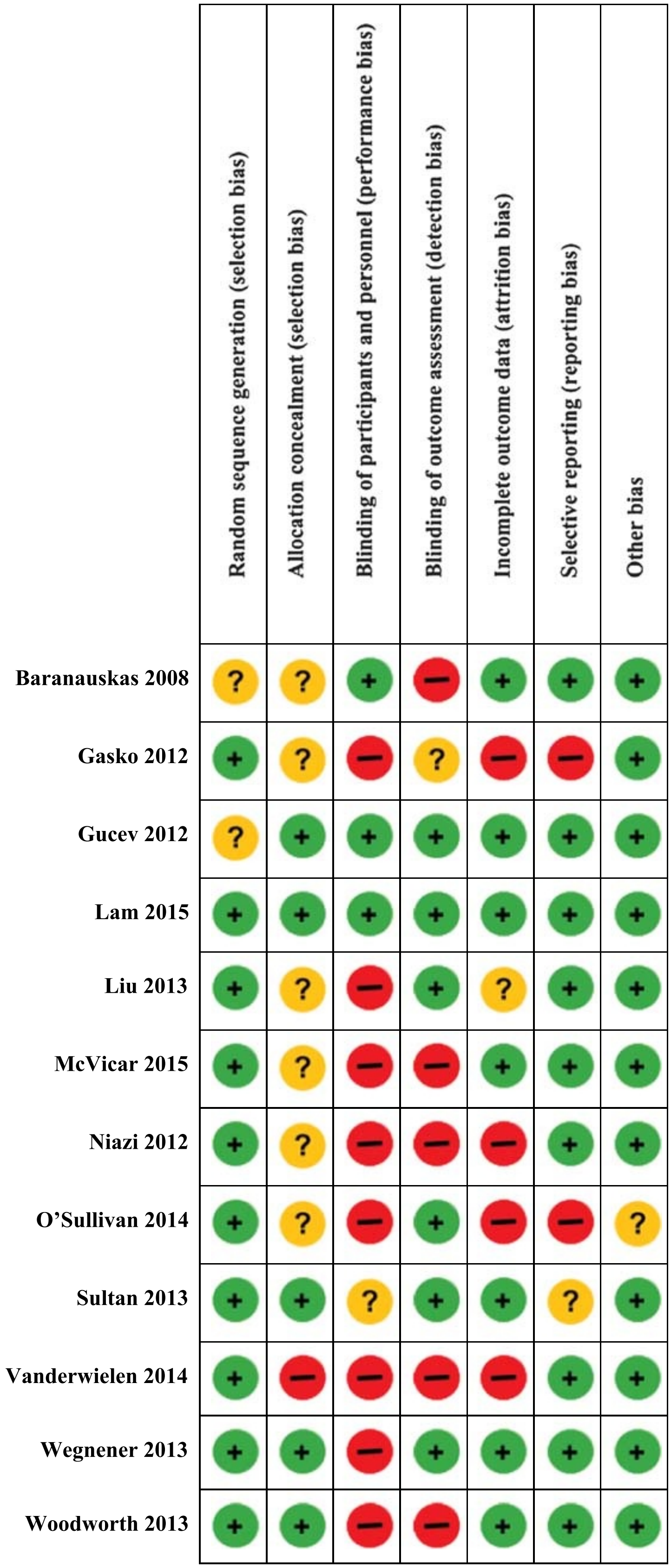

FIGURE 2. Risk of bias summary diagram (green = low risk, yellow = intermediate risk or unclear, red = high risk).

TABLE 3. Individual Study Information

Reference (Year)	Study Design/Location/Participant/n	Intervention Group/n	Control Group/n	Results	Conclusion	Outcome
Baranauskas et al[16] (2008)	RCT/Brazil/anesthesia residents/n = 9	Group 1 (G1), theoretical explanation and 2 h of practical training/n = 3	Group 2 (G2), theoretical explanation and 1-h of practical training/n = 3; or group 3 (G3), theoretical explanation only/n = 3	The mean length of time to perform the tasks was 37.6 s for G1, without technical flaws; 64.4 s for G2, with 2 technical flaws; and 93.8 s for G3, with 12 technical flaws	Study concludes that the longer training of ultrasound-guided peripheral nerve block in an experimental model improved the learning curve of the technique	Skills
Gasko et al[17] (2012)	RCT/USA/student nurse anesthetists/n = 33	Combination of CD-ROM and simulation training/n = 7	CD-ROM alone/n = 11 or simulation training alone/n = 11	Combination teaching is better at increasing scanning performance than CD-ROM or simulation alone. No difference in scanning performance between CD-ROM and simulation alone groups	Using a combination of CD-ROM and simulation should be considered in teaching UGRA techniques	Knowledge and skills
Gucev[18] (2012)	RCT/USA/subjects had to have completed an anatomy course and had no experience in UGRA/n = 39	Cognitive Task Analysis–based instruction method using high-fidelity simulator/n = 19	Traditional UGRA instruction method using high fidelity simulator/n = 20	The experimental group performed significantly better in knowledge testing ($P < 0.05$) and required shorter times for completing the task when compared with the control group ($P < 0.05$)	The results of this study strongly support the hypothesis that Cognitive Task Analysis–based instruction in UGRA is more effective than conventional clinical teaching	Knowledge and skills
Lam et al[19] (2015)	RCT/USA/volunteers who were at least 18 y of age, right-handed, in good health, and with no previous ultrasound experience/n = 35	Using the See, Tilt, Align, and Rotate (STAR) method for needle visualization/n = 18	Using the traditional Align, Rotate and Tilt (ART) method for needle visualization/n = 17	The STAR group was able to complete the task more quickly ($P < 0.001$) and visualized the needle in a greater proportion of the procedure time ($P = 0.004$) compared with the ART group. All STAR participants were able to complete the task, whereas 41% of ART participants abandoned the task ($P = 0.003$)	Novices are able to complete a simulated ultrasound-guided nerve block more quickly and efficiently when trained with the 4-step STAR maneuver when compared with the ART method	Skills
Liu et al[20] (2013)	RCT/USA/anesthesia staff providers with limited experience of UGRA (<20 successful UGRA in the past)/n = 36	Opaque model/n = 12	Clear phantom model/n = 12 or olive-in-chicken phantom model/n = 12		Training on inexpensive synthetic simulation models with no perishable products permits learning of UGRA skills by novices	Skills

Continued next page

TABLE 3. *(Continued)*

Reference (Year)	Study Design/Location/ Participant/n	Intervention Group/n	Control Group/n	Results	Conclusion	Outcome
McVicar et al[21] (2015)	RCT/Canada/medical student with no previous ultrasound experience/n = 26	A group who performed the task using an ultrasound machine equipped with an ultrasound needle guidance positioning system (SonixGPS)/n = 13	Conventional ultrasound group/n = 13	The needle guidance group reached competence more often. This group had fewer attempts and quality-compromising behaviors than did those using conventional ultrasound	Use of the SonixGPS ultrasound needle guidance system improves the performance of technical needling skills of novice trainees in an ex vivo model	Skills
Niazi et al[22] (2012)	RCT/Canada/second-year postgraduate anesthesiology residents with no experience with UGRA/n = 30	4 didactic lectures plus 1-h low-fidelity simulation training/n = 10	4 didactic lectures on peripheral nerve blockade at the beginning of rotation plus self-education/n = 20	The conventional training group had 98 successful blocks, and the simulation group had 144 (51.3% vs 64%; $P = 0.016$). In the conventional training group, 4 of 10 residents achieved proficiency, and in the simulation-training group, 8 of 10 residents achieved proficiency (80% vs 40%; $P = 0.0849$)	Simulation training improves success rate in ultrasound-guided performance of regional anesthesia	Skills, and patient outcome
O'Sullivan et al[23] (2014)	RCT/Ireland/anesthesia residents with NO experience with UGRA/n = 10	Initial standardized training plus additional simulation-based training/n = 4	Initial standardized training and no further simulation-based training/n = 4	There were no statistically significant difference in clinical performance, as assessed using the sum of a Global Rating Score and a checklist score, between simulation-based training (mean, 32.9 [SD, 11.1]) and control trainees (31.5 [SD, 4.2]) ($P = 0.885$)	Although the study was discontinued early because of technical issues, its methodology can be used in future trials assessing learning efficacy associated with simulation-based training	Skill, behavior, and patient outcome
Sultan et al[24] (2013)	RCT/Ireland/fourth-year medical students with no previous ultrasound experience/n = 30	Group knowledge of performance (KP) participants received feedback after the end of each task series/n = 10; group knowledge of results (KR) participants received feedback after the end of each session/n = 10	Group C participants received no feedback/n = 10	Error reduction was significant over time intervals measured and also in between groups with significant difference between control:KP ($P < 0.001$) and KR:KP ($P = 0.001$) but not between control and KR groups. Marked and similar levels of skill attrition were identified in all 3 groups 24 h after the learning phase	When feedback was based on KP, novices acquired predefined skills more quickly and made fewer errors during the learning phase when compared with controls. When the feedback content was based on KR, novices acquired predefined skills more quickly but made similar numbers of errors during the learning phase when compared with controls	Skills

Vanderwielen et al[25] (2015)	RCT/USA/anesthesia residents and staff/n = 50	Gel phantom and instructional video group/n = 18 or gel phantom group with no instructional video/n = 17	Control group, did not receive any instructional training intervention beyond anesthesia residency training and/or clinical practice experience/n = 15	Perceived knowledge of basic spinal anatomy and spinal sonoanatomy improved in the intervention vs control groups	Use of hands-on gel phantom or instructional video training can improve anesthesia staff and resident knowledge of lumbar spine sonoanatomy	Knowledge
Wegener et al[26] (2013)	RCT/the Netherlands/anesthesia residents and staff with limited or no experience with UGRA/n = 35	(Group T) Identified anatomical structures on a live model using an ultrasound machine with a built-in tutorial/n = 17	(Group S) Identified anatomical structures on a live model using a standard ultrasound machine/n = 18	Group T scored significantly higher (16.8 T 3.6 [62%] vs 13.4 +/− 4.4 [50%], $P = 0.018$), whereas time required was longer (1053 vs 740 s, $P = 0.001$)	An electronic tutorial can help novices in UGRA identify anatomical structures	Knowledge and skills
Woodworth et al[27] (2014)	RCT/USA/anesthesia residents, fellows, and community anesthesiologists with varied ultrasound experience/n = 28	Given a short educational video regarding ultrasound anatomy plus time to experiment with computer-based simulator after the pretest/n = 16	A group who had a sham video after the pretest/n = 7	Mean postintervention written test scores in the intervention group were greater than those in the control group. No difference was noted in posttest live-model scanning. While the intervention group had improved confidence, there was no difference in time required to perform an ultrasound scan of sciatic nerve when compared with control	A short educational video with interactive simulation significantly improved knowledge of ultrasound anatomy, but failed to improve hands-on performance of ultrasound scanning to localize the nerve	Knowledge and skills

prematurely aborted and as such has great concern with respect to internal validity.[23] Without considering these suggested changes in UGRA simulation research, it is unlikely that decision makers will devote the necessary resources and personnel toward this venture. Further studies with robust methodology assessing learning at the workplace and the cost-benefit relationship of simulation-based UGRA training are required to identify if implementation of these curricula is fiscally feasible and precisely what the benefits are to patient outcomes, if any.

CONCLUSIONS

This systematic review found that UGRA simulation training significantly improves learners' knowledge and skills. These acquired UGRA skills may be transferred to the clinical settings; however, further large-scale, well-designed, and rigorous studies are required to confirm that these acquired skills translate into improved patient care.

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