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REVIEW ARTICLE

Effectiveness of Ultrasound Simulation in Obstetrics and Gynecology Education: A State-of-the-Art Review

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ABSTRACT

Introduction: The benefits and uses of ultrasound (US) are well documented for procedural and diagnostic purposes. A number of studies have evaluated the utility of simulation-based US training in achieving competency and improving safety. To the best of our knowledge, no previous studies have attempted to synthesize the effectiveness of US simulation in Obstetrics and Gynecology (OB GYN) education using a systematic method. This review article summarizes the effect of US simulation on learning outcomes in OB GYN with three objectives: (1) To review and summarize the available evidence on the effectiveness of US simulation in OB GYN; (2) determine the validity and usefulness of US simulation in OB GYN training; and (3) describe advantages and disadvantages of various US simulators available in OB GYN as of 2016.

Materials and methods: We performed a literature search using different search engines, such as Medline PubMed and EMBACE using appropriate keywords. The data were extracted from all published eligible studies. A meta-analysis was conducted in order to obtain a pooled estimate of effect of US simulation in OB GYN education based on the availability of data on common outcomes.

Results: The majority of the included studies supported the usefulness or validity of simulation training in OB GYN for the enhancement of US skills. The US simulation significantly improved the skills necessary to measure crown-rump length and nuchal translucency accurately.

Conclusion: Despite the cost, integration of US simulators in medical education appears to have a positive impact on the scanning and interpretation skills of trainees. This study may assist in preparing a dedicated curriculum for OB GYN US education via the inclusion of US simulation.

Keywords: Clinical skills, Gynecology, Obstetrics, Training, Ultrasound education, Ultrasound simulation

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INTRODUCTION

Ultrasound (US) is the most commonly used diagnostic tool for prenatal assessment and evaluation of various gynecological pathologies. While US is continuously enhancing the practice of obstetrics and gynecology (OB GYN), there is lack of standard curriculum and performance assessment tools to monitor trainees' improvement. There is a wide range of US skills among trainees and practitioners. Training standards and assessment of competency are not standardized among residency programs. In today's OB GYN training programs, US skills are primarily gained through clinical exposure at the cost of patient discomfort and safety. Training in US is highlighted as a top deficiency by residents.[1] Due to insufficient competency at the basic level, there is a concern over safety and efficiency of US examination performed by resident physician novices. Patient encounters with novices who do not have appropriate training can lead to compromised patient care, unnecessary intervention, and additional testing.[2,3] In a recent survey of 70 OB GYN residents, 50% of them failed to achieve US competencies required for the stage of training and reported limited exposure to dedicated US sessions, while 73% of them considered US simulation to be an essential component of their residency training which may improve their clinical and interpretation skills.[4] The US is operator-dependent, requires manual dexterity and eye-hand coordination, as well as a thorough understanding of anatomy, physiology, and pathophysiology. Also, US training is time-consuming and requires extensive exposure to various normal and abnormal clinical scenarios.[5]

The American Institute of Ultrasound in Medicine (AIUM) has provided guidelines and standards for US training. They require 3 months of US training or a

minimum of 300 US examinations as a part of a residency or fellowship before independently performing and interpreting female pelvic US.[6] The International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) has published guidelines for basic US training for residents and suggested a minimum of 200 OB scans for residents in OB GYN.[7,8] The US skills correlate with number of scans or procedures performed, and may be influenced by duty hour restrictions of trainees and reduced exposure time to US training.[9,10] In the current era, educators focus on achieving sufficient competence to deliver safe and effective patient care in a nontraditional method like simulated environment. Residents, fellows, and sonography students should be exposed to simulation-based training to maximize learning within few duty hours, achieve the highest possible performance level before US encounters with real patients, and improve patient safety.

A recent narrative review describes the US simulators used in OB GYN.[11] However, this study does not provide information on the effectiveness of US simulation for US training and its validity. Until now there have been no attempts to analyze the overall evidence of the educational and competence benefits of US simulation and the transferability of simulation skills to the clinical OB GYN using a systematic review. We intend to summarize the effectiveness of US simulators in improving the performance of US skills in OB GYN with the following specific aims: (1) To review and summarize the available evidence on the effectiveness of US simulation in OB GYN; (2) determine the validity and usefulness of US simulation; and (3) describe advantages and disadvantages of various US simulators in OB GYN available as of 2016.

MATERIALS AND METHODS

Data Analysis

A literature search was performed within the electronic databases MEDLINE, PubMed, and EMBASE®. A total of 128 articles were obtained initially using the combination of search terms "US simulator OR US simulation" AND "Obstetrics and Gynecology" AND "US education or education" AND "clinical performance OR clinical skills or learning outcomes" AND/OR "validity". Any studies, which evaluated the impact of US simulation education on at least one learning outcome in OB GYN US, such as accuracy in measuring biometry, were included in this review. Review articles, non-English articles, and abstracts were excluded from the study.

A manual review of titles and abstracts produced 78 articles, which met the inclusion criteria. Further examination of the full articles and the identification of duplicates revealed that 63 articles did not meet the inclusion criteria. Sixteen articles met the inclusion criteria and were included in this systematic review. The outcomes and conclusion of each study were summarized. A meta-analysis was carried out using a fixed effect models to obtain a pooled estimate for the satisfaction proportion and crown-rump length (CRL) outcome.

RESULTS

With rare exception, all of the studies on the usefulness or validity of simulation training in OB GYN reported an enhancement in US skills after the use of simulation.[1] Table 1 summarizes the studies assessing the characteristics and outcomes of OB GYN US simulation.[11-18] Over a span of 13 years, we identified 10 articles which evaluated the impact of the use of US simulation training on different outcomes in OB GYN. The majority of these studies evaluated the effect of US simulation through varying study designs, such as a prepost experimental study,[11,14] nonrandomized interventional study,[13,16] observational study,[12,15] and randomized clinical trial.[17] Of these studies, most of them (n = 9) were based on small sample sizes (≤50). The two randomized studies produced contradictory findings; Skupski et al[17] reflected that simulation-based training showed inferiority compared to live model in regards to the primary outcomes (rating of training, scanning technique, and image acquisition), while Tolsgaard et al[12] demonstrated that simulation-based US training improved the performance compared to clinical training only. The latter study performed a randomized trial using a control, clinical training only group.

First Trimester Screening

Of the total studies included in this review, two assessed the impact of US simulation training on CRL and nuchal translucency (NT) measurements.[13,14] These two studies found that US simulation significantly improves the skills required to measure CRL and NT accurately and may reduce false results.

Anatomy Scan

US is used to evaluate fetal anatomy and detect fetal structural abnormalities.[15] The incidence of fetal anomalies is 2% for major, and 5% for minor anomalies.[16-18,26] Compared with other diagnostic tools, the sensitivity of US in detecting anomalies is far less than perfect since a lot depends on the operator. Some multicenter studies from the early 1990s demonstrated no reduction in perinatal morbidity or mortality since the introduction of US.[27,28] We may argue that this outcome is a consequence of the current training style, which involves theoretical knowledge gained by means of lectures and textbooks, and practical knowledge gained by exposure to as many patients as possible. The currently available high-fidelity

Table 1: Summary of OB GYN ultrasound simulation studies illustrating improvement in ultrasound performance

Author/ Reference	*Year*	*Sample size*	*Sample population*	*Simulator type*	*Activity*	*Outcome*	*Conclusion*
Pittini et al[19]	2002	30	12 medical students and PGY1, 15 senior residents PGY3-5, 3 MFM fellows	Self-developed US simulator; Details N/A	Comprehensive simulator based curriculum for amniocentesis was developed; Performance was assessed by using 2 scales (GRF and DCL)	Performance score improved with US simulation	Ultrasound simulator is effective in enhancing ultrasound performance
Maul et al[13]	2004	45	Certified obstetricians (24 had theoretical training; 21 had theoretical training plus training on simulator)	Sono Trainer	CRL and NT on 9 pregnant volunteers in 1st trimester	Comparison of CRL and NT measurements	Ultrasound simulation significantly improves skills for accurate measurements of CRL and NT
Maul et al[13]	2004	7	7 OB GYN experts	Sono Trainer	Each expert evaluated 10 US scans (8 normal and 2 abnormal fetal scans)	Fetal anomalies were identified by 5 experts	US simulation can be used to train fetal anomaly scan
Heer et al[20]	2004	49	25 OB GYNs experienced in US; 24 4th year medical students with no experience in OB GYN US	Software-based training system	3 GYN scans on “virtual patient” by each participant	Equivalence of VR with live investigations in OB GYN US	VR scanning is similar to performing OB GYN US and allows standardized US teaching
Staboulidou et al[21]	2006	1,266	All experienced OB GYNs	SonoFit	OB basic US course using SonoFit US simulator; Questionnaire based survey before and after courses	Improvement in basic standardized quality of training, skills and sonographic knowledge in prenatal medicine	US simulation is useful and effective in in structured sonographic training
Burden et al[22]	2011	30	All OB GYNs; 3 groups a) Novices (<10 US performed; b) Intermediate (20–50 US performed); c) Experts (>100 US performed)	UltraSim	Each participant did 5 subsequent CRL scans and 3 biometry measurements (BPD, OFD, FL)	Mean percentage deviation from target for all measurements and time taken to perform each scan; Level of accuracy and speed improved with repetition among beginners	VR simulators are useful to improve scanning skills for OB GYN trainees
Burden et al[23]	2013	26	18 OB GYN trainees; 8 certified OB GYN US experts	UltraSim	Each participant did 5 subsequent CRL scans and 3 biometry measurements (BPD, OFD, FL); Mean percentage deviation from target for all measurements and time taken to perform each scan	Level of accuracy and speed improved with repetition among beginners	VR simulators useful before clinical sessions
Madsen et al[24]	2014	28	16 final year medical students (US novices) and 12 OB GYN consultants (experienced US practitioners)	Scan Trainer	Each participant completed the seven valid modules (basic to advanced GYN) twice	Evaluation of learning curves for US novices on VR simulator; Novices performance improved with practice on US simulator	Competence in the performance of OB GYN US can be assessed using VR simulation
Moak et al[25]	2014	134	3rd year medical students	Blue phantom/ female pelvic models	RCT comparing pelvic US simulator and live model training for training in endovaginal sonography (IU pregnancy and ectopic pregnancy)	Scanning technique, image acquisition and rating of training were better with live model	Simulators do not perform as well as live models for training novices
Tolsgaard et al[12]	2015	33	18 novices (new GYN residents) had simulation based training followed by clinical training; 15 novices had clinical training only	Scan Trainer	2 months of clinical training in US for all; Intervention group (n = 18) had simulation training in addition; Clinical performance on real patients was tested	Intervention group scored higher OSAUS score, clinical performance test	Simulation-based training in addition to clinical training has sustained positive impact on clinical performance

RCT: Randomized clinical trial; GRF: Global rating form; DCL: Detailed checklist; N/A: Not available; VR: Virtual reality; OSAUS: Objective structured assessment of ultrasound skills (consisting of image optimization, systematic exam, interpretation of images, documentation, and medical decision-making); MFM: Maternal Fetal Medicine

US simulators can simulate almost every imaginable US examination and may ultimately reduce the need of hired models and patients for early learning. The systematic use of US simulation may improve the detection rate of congenital fetal anomalies; improve the learning curve, self-assessment, and objective evaluation of the learner's competency.[13] The training agenda for individual trainees can be modified depending on the desired pace of the acquisition of the required skills.

Biometry

SonoTrainer was used by experts and demonstrated improvement in accurate CRL and NT measurements and supported the idea of introducing simulation-based training into clinical learning.[13] The majority of participants reported good image quality and excellent training effect with the use of SonoTrainer US simulator. Using UltraSim, Burden et al[23] reported improvement in efficiency in obtaining biometry measurements, the accuracy (mean deviation in the measurements of fetal biometry from target values), and placental localization. They also reported that the simulator was easy to be used by novices as well as experienced operators and noticed quick adaptation to the simulator.[29] Akoma et al[30] evaluated the role of a fetal pig simulator in OB US training in 24 participants who were randomized to two groups with 12 learners in each group. Only hands-on scanning on pregnant patients was used for the first group (patients between 16 and 28 weeks gestation), and hands-on scanning plus fetal pig simulation for the second group. No difference in biometric scan between the two groups was observed, but the intervention group (hands-on scanning plus fetal pig simulation) obtained improvement in scanning time and the acquisition of adequate images. The conclusion of this study was that the addition of a fetal pig US task trainer improved US scan efficiency.

Prenatal Procedures

Since the focus in health care is shifting to better prenatal outcomes per center, in-training physicians should achieve the best skills possible in order to perform critical procedures that can improve fetal survival. Teaching and training can be challenging especially for "not so commonly performed procedures" like fetal surgeries. The rate of invasive procedures has dropped significantly in the past 6 years due to the increased use of improved screening tests.[31] The use of noninvasive cell-free fetal DNA testing is likely to continue to cause a decline in the use of invasive testing. In order to increase the expertise of fellows within the limitation of a declining number of invasive procedures, the role of simulation should be explored and the American Congress of Obstetricians and Gynecologists (ACOG) should consider guidelines to maximize trainees' experience.[32] Rose et al[33] indicated that simulation-based training may help preserve and improve those procedural skills.

Amniocentesis, chorionic villi sampling (CVS), in-utero stent placement, percutaneous umbilical cord blood sampling, and cervical cerclage are the areas where simulation has great potential benefit.[34] It is anticipated that more fetal surgeries will be performed in the future due to the increasing incidence of multiple gestation (increasing use of assisted reproductive technologies and advanced maternal age), economic growth, and heightened awareness of fetal surgeries. McWeeney et al[35] reported that maternal-fetal medicine (MFM) fellowship programs are not able to provide sufficient training in CVS. Therefore, they developed a novel training model using a porcine heart, piglet, and freezer bag with US gel to simulate abdominal wall and use of transabdominal sonogram to guide CVS performance. All MFM faculty and fellows agreed that the model was useful.[35] Nitsche et al[36] created a novel in-utero stent placement training model using a gravid pig uterus. This kind of low-cost task trainer was utilized to enhance skills in a nonclinical environment. Zubair et al[37] developed a novel amniocentesis model by using formalin-preserved gravid pig uterus and a freezer bag filled with US gel placed on the top of the uterus to simulate the abdomen. Changing the fetal position and amniotic fluid and gel thickness simulated realistic scenarios. Simulation-based curriculum examples helped trainees learn amniocentesis early in their training with no discomfort to patients from practice trials.[38] Peeters et al[39] reported improved performance of fetoscopic laser surgery in twin-to-twin transfusion syndrome with the use of advanced high-fidelity simulator. Experts as well as novices reported the usefulness of simulators and felt that the use of simulation improved their performance score and reduced procedure time. Similarly, the use of a task trainer for simulation of ultrasound-guided second trimester uterine evacuation improved proficiency and confidence with dilatation and evacuation procedures among residents and other trainees.[40]

Pelvic Ultrasound

Madsen et al[24] reported that the virtual reality (VR) simulator is a reliable and valid tool to improve pelvic US examination performance. In their study various advanced pelvic modules were used and authors observed improvement in novices' performance, which plateaued after 4 hours of simulation training. Girzadas et al[41] demonstrated improvement in knowledge, diagnostic skills, and management of a ruptured ectopic pregnancy using a hybrid simulator compared to a standard high-fidelity simulator. The hybrid simulator consisted

of a transvaginal US task trainer combined with a high-fidelity US mannequin. Vallabh-Patel et al[4] reported improvement in clinical knowledge and interpretation of images skills in a clinical setting with the use of low- and high-fidelity transabdominal and transvaginal pelvic US simulators. Monsky et al also reported improved knowledge and scanning ability following early pelvic US simulation for residents.[42]

Ultrasound Learning for Trainees

Steps should be taken to develop a standard curriculum, dedicated and effective training for OB GYN residents, fellows and practicing physicians to improve and preserve their US scanning and interpretation skills. Credible performance standards should be reached before encounters with actual patients. Based on our systematic review, there is a benefit of including simulation courses and dedicated curricula for different level of trainees using different modules. A standard US curriculum, similar to what was developed for MFM fellowships, which incorporates the introduction of US simulation at an early stage for the novices in OB GYN training is of paramount importance.[43] For improvement in US education among OB GYN residents and its subspecialties, clear educational goals and objectives, and valid performance rating should be established.[44,45]

Three major competencies in US are as follows: (1) Technical aspect of performance, (2) image perception, and (3) interpretation – medical decision-making skills.[2,45,46] For the objective assessment of US skills, international multispecialty consensus suggested seven elements: (1) Indication for the examination; (2) applied knowledge of US equipment; (3) image optimization; (4) systematic examination; (5) interpretation of images; (6) documentation of examination; and (7) medical decision-making.[47]

Validity of Various Simulators

Limitations of the first generation of VR simulators are static images of the fetus, lack of heart activity, and no blood flow. Additionally, there is no adiposity effect and given the increasing prevalence of obesity the addition of this feature in upcoming advanced simulators will be very helpful. These real-time properties of US simulation were improved in recent models. Most studies variably demonstrated acquisition of knowledge and skills and generated findings, suggesting a correlation with simulation training and improved performance in the simulated environment.[12,19-25,13] This finding may be acceptable provided the simulator is appropriately validated (in many reports, i.e., debatable). Some studies examined the question of validity concurrently or in isolation, so there is limited evidence on construct validity of simulators.[11,14,29,48-50] Though literature on the use of US simulation is sparse, it consistently showed its usefulness in US education in OB GYN.

Burden et al demonstrated construct validity of the UltraSim simulator in performance of CRL and growth scan measurements, and stated that this high-fidelity simulator has the potential to improve the scanning skills of OB GYN trainees.[51] Newey et al[14] have demonstrated the validity of VirUS for NT measurement. More recently, Patel et al[51] explored the OB GYN trainees' perspective on the use of VR US simulation in the United Kingdom. Of 140 trainees, 70 (50%) responded to the survey; 73% of respondents considered US simulation to be an essential component of training; 69% agreed that it helps improving their clinical skills; 77% would like to have US simulation integrated into OB GYN training. Table 2 reviews the studies evaluating the validity of OB GYN US simulators.[17,22,24-26,33,51]

There is limited reported evidence on the transferability and sustained effect of US simulation training-based skills to the clinical setting. This paucity of literature could be due to the lack of simulator metric validity and a standard measuring tool for performance. Figure 1 shows the satisfactory rating of US simulators in the improvement of clinical knowledge and image interpretation skills in the clinical setting. The pooled meta-analysis showed a high satisfactory rating proportion of 84% (95% confidence interval: 79–90%) without significant heterogeneity (68.7% considering 70% or more as presence of heterogeneity).

Types of US Simulators

Currently, there are three types of US simulators.

1. *Online*: Web-based programs that use mouse-operated controls to change scan planes and simulate probe manipulation, and display US images corresponding to the particular scan plane. To our knowledge, there is no clinical validation of this method.
2. *High-fidelity mannequins*: Consisting of the mannequin, simulator, US probe, computer, and monitor. The display uses virtual anatomic model images with augmented reality and US rendered images or actual US images from a stored dataset.
3. *Phantoms*: Use of a real US unit to image a phantom to practice diagnostic and/or procedural skills (e.g., echocardiograms-solid heart model to demonstrate cardiac anatomy and scan planes, amniocentesis phantom, etc.).

Table 3 reviews the currently available OB GYN US simulators.[11,16,17,22,33,48-51,52-73]

Limitations of OB GYN US Simulation

The inconsistency in study design and measurement items across the studies that were included in our review

Table 2: Review of studies evaluating the validity of OB GYN US simulators

Author, year and reference	*Sample size*	*Sample population*	*Simulator type*	*Activity*	*Outcome*	*Conclusion*
Newey et al[14]	13	Experienced sonographers	VirUS	NT repeatability, inter- and intraobserver measurement	Significant correlation between repeatability	Potential use of simulator in operator training
Burden et al[29]	26	18 OB US trainees and 8 certified experts	UltraSim	Each participant did five subsequent CRL scans and three biometry measurements (BPD, OFD, FL)	Mean percentage deviation from target for all measurements and time taken to perform each scan; Trainees had greater variation of measurements on simulator and took longer time to scan	UltraSim has construct validity
Alsalamah et al[48]	36	25 experienced and 11 independent practitioners; both groups were new for the simulator	ScanTrainer	Transvaginal US training	10 point Visual Analogue Scale	Scan trainer has face and content validity; Reported as beneficial tool for teaching US skills
Al-Memar et al[49]	24	Three groups, each had 8 participants: (1) Novice trainees; (2) Intermediate level trainees; (3) Experts	ScanTrainer;	Each participant completed two modules (GYN and early pregnancy modules)	Questionnaire using five-point Likert scale	Face and content and construct validity; Reported as a valid training tool for GYN US training; Participants agreed that simulator played a positive role in US training
Chalouhi et al[17]	29	OB GYN and radiology consultants (n = 12); Midwives (n = 13); Physicians (n = 14);	VIMEDIX	Each candidate scanned volunteer pregnant patients and used OB GYN simulator; Each candidate obtained nine biometric and morphological planes on patients and simulator; Scans were scored and compared by two reviewers	Mean dexterity score in simulation and real US examination were comparable	OB GYN US simulator is a good method to evaluate skills of trainees; It is comparable to evaluation in pregnant volunteers
Preshaw et al[50]	25	Trainees and experience sonographers (details N/A)	ScanTrainer	Anonymous survey on functionality, realism and role of ScanTrainer in developing US skills	ScanTrainer bridges the gap and helps novices to learn practical skills and principles of US scanning	Novices should develop initial US skills using simulation-based training
Patel et al[51]	140	OB GYN trainees	Nonspecified VR US simulators	Anonymous survey on US simulation training	73% of respondents considered US simulation to be an essential component of training; 69% agreed that it helps improving their clinical skills; 77% would like to have US simulation integrated into OB GYN training	US simulation has the potential to improve the use of currently available resources in clinical US education and may enable trainees to achieve mandatory US skills

BPD: Biparietal diameter; FL: Femur length; AC: Abdominal circumference; OFD: Occipitofrontal diameter; NT: Nuchal translucency; US: Ultrasound

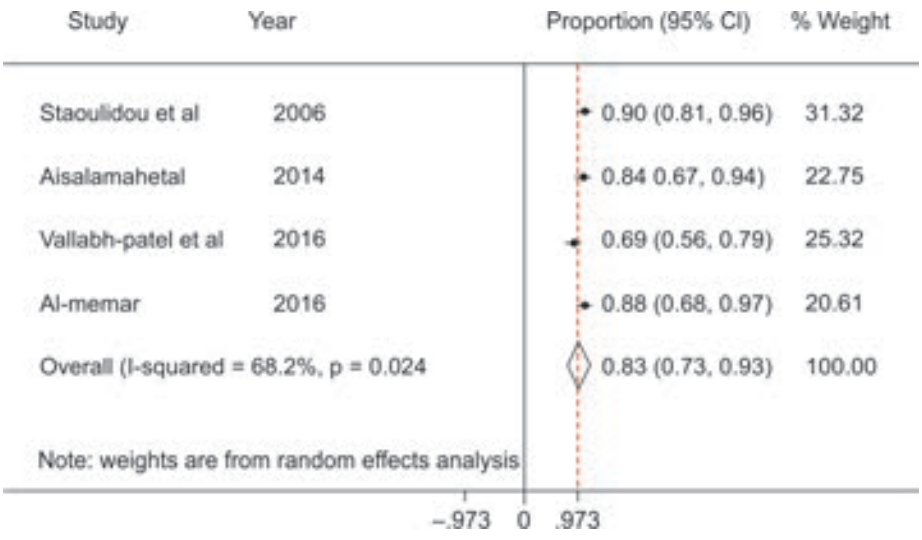

Fig. 1: Rating of ultrasound training using simulators

precluded a broader meta-analysis of the effect of US simulation on OB GYN education. In most studies the scoring system used to measure improvement was not standardized and pre- and posttest analysis was not done consistently. In some studies a control group was lacking, and the US experience of comparison groups was not clear. Our review did not include the results of unpublished research studies and non-English language studies, and a more comprehensive review of the "gray" literature was not performed. Despite the limitations stated above, nearly all of the included studies reported substantial improvement in clinical knowledge, skills, and confidence following the use of OB GYN US simulation.

CONCLUSION

In surgical fields simulation-based training has already been incorporated, with proven benefit in procedural skills.[52-54] Simulators are not perceived as a replacement of clinical training but rather as an aid to speed up the basic, as well as advanced skills learning curve. A simulator is an educational tool, which imitates real-life scenarios, closely approximates patient encounters to develop knowledge and skills that can be transferred to the clinical setting to improve patient safety and efficiency. The goal of simulation is to help the learners become more confident and competent when caring for their patients.[55] Additional benefit of simulation is the reduction of patient discomfort. Simulation also provides an opportunity for independent learning and limits the need of supervision. The US simulation is expected to improve efficiency and diagnostic skills resulting in the decreased need of expensive imaging tools, such as computed tomography and magnetic resonance imaging. Simulation-based training is gaining more popularity in all medical specialties, and following the introduction of simulation improved outcomes have been widely reported.[44,56] The US simulation is a safe, effective, and learner-centered educational approach which improves image optimization and probe orientation, provides the opportunity for unlimited practice without pressure, and facilitates a systematic approach to sonography prior to the patient encounter (Fig. 2).[11,29,33,47,57-59]

Patient discomfort and the intimate nature of endovaginal sonography encourage the need of simulation-based learning. Our systematic review reports significant improvement in clinical knowledge, skills and behaviors; and moderate effects for patient-related outcomes with the use of US simulation in training.[11,15,24,67] However, the present studies failed to demonstrate a compelling body of evidence to support widespread adoption of US simulation-based OB GYN education to improve US performance skills.

Trainees with varied exposure to simulation found US simulation to be useful. Trainees also expressed a desire for more substantial incorporation of US simulation in their training.[51] There is limited but supportive literature on the usefulness of OB GYN US simulation, which reveals that it not only improves the scanning skills of trainees and detection rates of abnormal findings but also helps providers preserve their skills. It is not surprising to see transferability of US skills to the clinical area, though not many studies investigated this effect. Despite the cost, integration of US simulators in medical education seems to have a positive implication on the scanning and interpretation skills of trainees.

We hope that this review will encourage various training programs to include US simulation in the education of their trainees with the ultimate goal of improving patient safety. More extensive clinical trials are needed to assess the long-term impact of US simulation on clinical

Table 3: Review of OB GYN US simulators

Reference (year)	*Simulator*	*Vendor*	*Modules for OB GYN*	*Application*	*Performance assessment capability*	*Properties*	*Data acquisition*
Cawthorn et al[60]; Park et al[61]	VIMEDIX OB GYN	CAE Health care, Sarasota, USA and Ville St Laurent, Quebec, CAN	Eight weeks fetus (allows TV scanning), fetus at 20 weeks (more than 20 birth defects included) GYN cases	OB GYN (TA, TV probe), echocardiography and TTE	Metrics to assess competency; visual clue to indicate pain with deep endovaginal probe insertion	Realistic with a dummy, high image quality, echocardiography with heart movement	Software generated, virtual patients based on real patient scan
***Tolsgaard et al[12]; Madsen et al[24]; Carolan-Rees and Ray[62]	Scan Trainer Professional	MedaPhor Ltd, Cardiff MedicentreWales, UK	Fetal 1st/2nd trimester with normal and various fetal anomalies, GYN cases with uterine pathologies and pelvic masses	OB GYN (TA, TV probe, B-mode, color and spectral Doppler); IM and EM modules	Curriculum based teaching, real-time assisted guidance, haptic feedback device, metric-based assessment	Realistic with a dummy, high image quality	3D data from real scans
Ehricke[63]	SonoSim	SonoSim, Inc. Santa Monica, CA, USA	1,000 actual patient cases	Point of care US learning modules for various specialties	No assessment tool available	PC based virtual US scanner; Graphical interactive simulation	3D data from real patients
Burden et al [33]; Meller et al[64]; Meller[65]; Knudson and Sisley[66]; Henrichs et al[67]; Kaufmann and Liu[68]; Schwid et al[69]; Zuvekas et al[16,70]	UltraSim	MedSim Inc. Lauderdale, FL, USA	Over 120 cases of fetus in all trimester, normal and various pathologies in OB GYN	OB GYN (TA, TV probe, B-mode, color and spectral Doppler), abdomen, breast, vascular, neck and EM	Provides measures to monitor performance	Realistic with a dummy, Interactive; Introduced in 1995; Pioneer in US simulation	3D data from real patients, configured into relevant modules
None	SonoMom^{TM}	SIMULABS USA Seattle, WA, USA	1st trimester complications (13 cases)	OB (TA, TV probe), EM	N/A	Realistic with a dummy, high image quality, real time	3D data from real patients
None	US Mentor	3D Systems Health care, Littleton, CO, USA	Fetal 1st tri (viability, GA assessment, NT, chorionicity and amnionicity); 2nd trimester modules offer moving fetus with normal and malformed cases; basic and difficult 4 GYN modules, 24 cases	OB GYN, cardiology, IM and EM; basic and advanced image enhancements, artifacts, color Doppler, CW, PW, M-mode, TA and TV probes	Metric assessment tool for all modules	Comprehensive and realistic modules with a dummy, high image quality, real patient-based cases	VR, computer rendering from real patient-based images
Maul et al[13]; Baier et al[71]; Wustemann et al[72]; Terkamp et al[73]	SonoTrainer	Sonofit GmbH, Stadecken-Elsheim, Germany	OB modules (1st and 2nd trimester, major and minor anomalies, fetal echocardiography), GYN modules (TA and TV)	OB GYN cases (TA, TV probe), breast, IM and EM, cardiology, TTE, urology	N/A	Realistic with a dummy, high image quality, real time, fetal echocardiography including heart movements	3D from real scans
None	Space Fan ST	Kyoto Kagaku, Tokyo and Nagya, Japan	23- weeks fetus model (biometry, placental localization and amniotic fluid anatomy assessment)	OB, breast and lung exam, EM	N/A	Oval-shaped phantom abdomen, medium image quality, no heart movements	VR based on real patient scan
None	Schallware US simulator	Schallware GmbH, Berlin, Germany	100 cases, normal and abnormal obstetrics and gynecology cases	OB GYN, cardiology, IM and EM; B- and M-mode, color Doppler	N/A	Realistic with a dummy, high image quality, echocardiography with heart movements	3D from real patient scans

N/A: Not available; 3D: Three-dimensional; TA: Transabdominal; TV: Transvaginal; AFI: Amniotic fluid index; GA: Gestational age; NT: Nuchal translucency; IM: Internal medicine; EM: Emergency medicine; TTE: Transthoracic echocardiography; CW: Continuous wave Doppler; PW: Pulsed wave; M-mode: Motion mode; B-mode: Brightness mode

Fig. 2: Simulation of ultrasound-guided procedures

performance with the use of a comprehensive curriculum including advanced simulators. Given that there has been only one randomized trial to date which tested the impact of US education incorporating a US simulator, additional randomized controlled trials are called for.[11] Further studies are needed to specify the number of sessions required to acquire and retain US skills, perform cost analysis, and assess validity and feasibility of the most recent US simulators.

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