The use of simulation in medical ultrasound: Current perspectives on applications and practical implementation (WFUMB state-of-the-art paper)

Claudia Lucius1, Michael Bachmann Nielsen2, Michael Blaivas3, Eike Burmester4, Susan Campbell Westerway5, Chit Yan Chu6, George Condous6, Xin-Wu Cui7, Yi Dong8, Gill Harrison9, Jonas Koch10, Barbara Kraus11, Christian Pålsson Nolsee12, Leizl Joy Nayahangan12, Malene Roland V. Pedersen13, Adrian Saftoiu14, Eric Savitsky15, Christoph F. Dietrich10,*

ABSTRACT

Simulation has been shown to improve clinical learning outcomes, speed up the learning process, and improve trainee confidence, while taking the pressure off initial face-to-face patient clinical areas. The second part of The World Federation for Ultrasound in Medicine and Biology state-of-the-art paper on the use of simulators provides a general approach on the practical implementation. The importance of needs assessment before developing a simulation-based training program is outlined. We describe the current practical implementation and critically analyze how simulators can be integrated into complex task scenarios to train small or large groups. A wide range of simulation equipment is available especially for those seeking interventional ultrasound training, ranging from animal tissue models, simple synthetic phantoms, to sophisticated high-fidelity simulation platforms using virtual reality. Virtual reality simulators provide feedback and thereby allow trainees to not only to practice their motor skills and hand eye coordination but also to interact with the simulator. Future developments will incorporate more elements of automated assessment and artificial intelligence, thereby enabling enhanced realistic training experience and improving skill transfer into clinical practice.

Key words: Ultrasound simulation; Training; Simple synthetic phantoms

ULTRASOUND SIMULATION: DEVELOPMENT OF TRAINING PROGRAMS

To achieve the overarching goal of simulation-based training, it is essential to follow a systematic approach when developing training programs. In medical education, a 6-step approach was proposed to ensure robust and focused curricular development.11 This approach starts with a needs assessment to establish what the current trainee requirements are before deciding what procedures to develop,2,3 followed by definition of goals and objectives including plans for assessment, decisions regarding educational strategies (ie, suitable equipment), rigorous implementation, and evaluation of both learning outcomes and program success.12

Decisions to develop simulation-based training programs are traditionally reliant on available commercial simulators with preference for more highly technical and innovative machines. The downside to this is that these expensive simulators will most likely end up underutilized if the need for training is not defined. A prioritized list of procedures was identified by key educational leaders as suitable for simulation-based training and can be used as a guide to developing training programs.13

Simulators alone will not ensure the acquisition of skills and competences in preparation for clinical practice. The development of structured simulation-based training programs should be based on evidence-based practices for optimal skills acquisition.14

Aside from providing a safe environment for skills training, simulation also provides a platform for evaluation of learning outcomes before clinical practice. It allows for the standardization of different assessment conditions such as the content, setting, and equipment
In Australia, clinical skills are developed using simulation and standardized patients before sonography trainees go onto placement, a model replicated in other courses around the world. Bowman et al. found that many skills were transferable to clinical practice, which reduced the pressure on the clinical placement site and impact on patient experience.

Difficulties arise not only in the correct visualization of specific anatomical structures but also in the general orientation to the sonographic cross-sectional image. The simulator can be integrated into the training setting particularly in the initially phase of orientation of the cross-sectional image. Virtual models of ultrasound images can be useful for this. A further step is to find and correctly assign the anatomical structures. Only when this is mastered does the detection of pathological patterns and organ areas on real-time ultrasound images of the respective simulation system follow. Later, defined pathologies are summarized into work packages and thus processed by the trainees on the simulator in a learning environment that is similar to a clinical environment. Simulation can fundamentally change ultrasound clinical placements and “... can prevent patients from bearing the burden of the initial steep part of trainees’ learning curve.” In 2015, a survey by the British Medical Ultrasound Society suggested that simulators could be used as a priority to gain hands-on experience before trainees interact with patients.

Simulation as an effective learning tool during the COVID-19 pandemic

Simulation also played a valuable role during the COVID-19 pandemic when social distancing was required. Training using simulation, rather than training directly on patients, improves patient safety. It also enables the instructor to be remote from the trainee. An instructor could potentially supervise a number of trainees in the same session via remote monitoring. For instance, during the pandemic, a practical hands-on ultrasound seminar for trainees at the Medical University of Hamburg with a special focus on child medicine was switched from a patient-centered course to simulation-based skills training session. Likewise, several ultrasound courses could take place in the Schallware Sim-Center in Berlin-Buch, with even providing single-place learning at the simulation platform.

Importance of automated assessment and virtual reality feedback elements

It should be recognized that self-directed, simulation-based training alone is not sufficient to gain competency. Learning without coordination and support from lecturers in ultrasound did not show the required level of competency. Providing direct feedback to trainees seems essential for successful learning. Therefore, virtual reality (VR) simulator-based training needs to include algorithms to use such systems in a truly self-directed manner.

Newer complex simulation systems offer not only the usual teaching/learning environment for simulators but also additional didactic refinements such as question and answer packages. This is one of the tools that can be used in formative, summative, and self-assessment of trainees. Comprehensive case studies are available, which can be studied by trainees in preparation for examinations or can be used as part of the final summative assessment. Typically, all results and measurements can be saved, allowing tutors to monitor progress and provide additional support.
Additional feedback can provide motivation to trainees; this can be achieved in a number of different ways, such as the following:

a) Use of set markers/areas that guide to the regions of interests
b) Predefined standard scans that can be controlled
c) Short question-and-answer parts that allows progress only with the right answer

Other elements might also be useful:

a) Further development from regions of interest to higher data volumes of interests (or segmentations) could allow recognition of standard scans
b) More focus on workflow training with checking those volumes of interests and correct examination sequences to gain skills transferable into clinical context
c) More elements of gamification, as this has been shown to be a promising education tool, for example, rewards for the correct answers/scans or competition by accuracy and time
d) Self-learn tutorials, combining instruction videos, self-directed learning, and question-and-answer, to achieve a certificate

Finally, the development of professional attributes and skills through sophisticated interaction between trainee and ultrasound simulator can improve interaction and communication with patients in a real-world setting.

**HOW TO TRAIN THE TRAINERS FOR SIMULATION**

Foremost, the trainers need to be motivated to use simulation tools. They should be experienced in ultrasound and learn to perform ultrasound examinations on the simulator themselves, in addition to teaching and pedagogical theory. First, they need instruction in handling the simulation software and hardware and gain knowledge of the technical components of the simulator(s) being used with basic troubleshooting so that they can realize data limitations and distinguish limitations due to the simulation mode. It also helps the trainer to understand simulation from the trainee’s perspective including the demands on concentration, interaction, and the intensity of training with simulators. Instructors can then adapt the curriculum according to these principles. Obviously, they should be familiar with the pathologies and details of the available instructions while also promoting professionalism within the simulation setting. One method of developing skills is a train-the-trainer course with support from a technician and a clinical trainer delivering simulation-based courses.

It is important to recognize the challenge left-handed trainees face when starting to use simulation. In clinical settings, left-handed trainees will soon adapt a right-handed scanning technique approach because of the equipment setup and placement of the patient; this needs to be encouraged when using simulation.

Individual feedback, in addition to the technical aspects mentioned already, is an essential part of any learning process and should be provided by experienced staff. Trainers also need a good understanding of how to capture the learning and to debrief trainees after simulated learning sessions.

Clear learning outcomes for simulated learning and debriefing after simulation should support trainees to reflect on the learning and how it can apply to the clinical setting. Different methods of debriefing can be used, and trainers must be familiar with best practice guidance.

An essential part of the trainer’s role is evaluating the simulation in relation to skills development and meeting the curriculum learning outcomes. As part of the training of the trainer, this should be considered to enable further refinement and development of the simulated learning space.

**SIMULATION IN INTERVENTIONAL ULTRASOUND**

Interventional ultrasound (INVUS) has evolved in the last 2 decades as the field progresses alongside innovative and sophisticated imaging modalities. Starting from the classic biopsy and drainage/puncture techniques, INVUS is now an integral component of transcutaneous abdominal and superficial ultrasound (US) as well as of various endoluminal US examinations such as transrectal, transvaginal, endobronchial, and endoscopic US. Successful INVUS procedures rely on competent operators who are knowledgeable about the normal and pathological US anatomy, puncture techniques, and principles, as well as stereotactic skills. These skills are traditionally attained during clinical rotations where a trainee shadows an experienced clinician. This apprenticeship approach is no longer sufficient, given the increasing focus on patient safety and strong initiatives to reduce preventable medical errors. The European Federation of Societies for Ultrasound in Medicine and Biology guidelines have recommended that training of INVUS procedures should start using simulation equipment to achieve the skills and competencies before performing those procedures on patients.

The different simulation equipment varies in terms of realism and purpose (for general approach, see part I of this state-of-the-art paper). Table 1 gives an overview of the basic competencies necessary for performing INVUS procedures with discussion of the possible role of simulation according to the desired training outcome. Although most VR simulators in the market offer interventional modules, the role of VR simulators for interventional skills training is limited at present. Future developments may improve the realism of simulated data and overcome the drawbacks outlined in Table 1.

Training models can meet most of the required objectives and competencies often referred to as part-task trainers because of their restriction to specific training skills. These include phantoms (ie, synthetic or physical models, block models, mannequin models) and animal tissue models.

- Animal tissue models, for example, chicken breasts and porcine shoulders or legs, are most commonly used to train basic US skill sets.
- These models are widely available; are not very costly; include natural structures such as bones, among others; and most importantly, provide the realism of tissue. Basic knobology and acquisition of ultrasonographic imaging can be developed using these models, as well as targeting by inserting an object such as an olive to simulate a mass or a cyst. Animal (tissue) models consist of parts of animal meat and have to be differentiated from so-called cadaver models. The latter are mainly used as human or animal cadaver for training of different kinds of complex emergency or surgery interventions—besides US training.
- Phantoms represent training models with certain anatomical regions to teach specific skills. These include commercially available synthetic models and simple custom-made or table-top models. The latter include gelatin and tofu agar-based models with embedded, different-sized targets such as grapes, olives, or peas. These are cost-efficient, are reproducible, and can be modified depending on the educational objectives. Some of the disadvantages include longer preparation time, visible needle tracks with frequent use, storage difficulties, and a short shelf-life of 2 to 3 weeks. In contrast, commercially available phantoms may
be more realistic, are portable, are reusable, and have a longer shelf life. They are offered as small block models, synthetic body parts (eg, arm or legs) or even whole mannequin models. However, they are not modifiable when needed; needle tracks can become visible after long-term use and are expensive. Some examples of commercially available phantoms to train in INVUS procedures are summarized in Table 2.

Despite the upsurge of simulators and the implementation of several training programs, the evidence supporting the effect of simulation-based training in US-guided procedures is not consistent through all clinical specialties. In summary, studies indicate a shorter learning curve by adding simulator-based training to clinical practice (European Federation of Societies for Ultrasound in Medicine and Biology guideline).[34] According to a recent systematic review, the main problems are the often insufficient study outcomes and the validation of a reliable assessment tool.[35–37] In the fields of respiratory medicine [37] and gynecology,[36] simulation training studies have been performed with sufficient methodology standards (ie, control group with other educational concept, randomized, single-blinded design). However, the aforementioned systematic review on simulation-based training of percutaneous abdominal and thoracic US-guided procedures revealed high risk of bias and insufficient evidence for the skill transfer into clinical context.[35] Future studies should overcome these shortcomings. The newly developed Interventional Ultrasound Skills Evaluation tool represents an important step in that direction. The Interventional Ultrasound Skills Evaluation tool covers comprehensively preprocedural planning, US technique, procedural technique, patient safety, communication, and teamwork.[6]

**SIMULATION IN EUS**

Basically, 4 different types of simulators can be distinguished for endoscopic use: in vivo models, phantoms, ex vivo or composite models, and VR simulators.[39]

### In vivo models

Training on living animals began in the 1970s,[40] initially using anesthetized baboons and dogs, and later pigs. Their anatomy and

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Competencies in interventional ultrasound and possible role of simulation</th>
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<tbody>
<tr>
<td>Competency</td>
<td>Objective Explanation</td>
</tr>
<tr>
<td>(1) Anatomy</td>
<td>Identification of structures, reference points</td>
</tr>
<tr>
<td>(2) Hand-eye coordination</td>
<td>Orientation within normal B-mode</td>
</tr>
<tr>
<td>(3) Needle-hand-eye coordination</td>
<td>Needle leading during in-plane and/or out-of-plane puncture</td>
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<tr>
<td>(4) Interaction needle-tissue</td>
<td>Interpretation of B-mode changes for assessment of correct needle tip location</td>
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**Table 2**

Examples of commercially available phantoms used in interventional ultrasound

<table>
<thead>
<tr>
<th>Name of the Simulator</th>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central line training model</td>
<td>Blue phantom by CAE</td>
<td>This model provides a realistic anatomy of the upper thorax and neck with different points of access including internal jugular, subclavian, infracavicular, and supraclavicular approach and access via the axillary vein. Doctors can use ultrasound with this phantom to guide the central venous access procedure.</td>
</tr>
<tr>
<td>Soft tissue biopsy ultrasound training block model</td>
<td>Blue Phantom by CAE</td>
<td>A simple yet realistic and ultradurable soft tissue biopsy ultrasound surgical training model. Trainees can use this to practice the psychomotor skills associated with ultrasound-guided fine needle biopsy procedures including transducer positioning and movement, recognition of tumors found in superficial anatomical structures, etc.</td>
</tr>
<tr>
<td>Venous and arterial line vascular access ultrasound trainer</td>
<td>Blue Phantom by CAE</td>
<td>This model allows for practice of inserting needle, guidewires and catheters in the brachial vein, basilic vein, radial artery, ulnar artery, and superficial veins.</td>
</tr>
<tr>
<td>Ultrasound needle breast biopsy phantom with amorphous lesions</td>
<td>CIRS Tissue Simulation and Phantom Technology</td>
<td>This model mimics that of an average patient in the supine position and has ultrasonic characteristics of tissues similar to the average human breast. There are 6 cystic masses and 6 dense masses, which are randomly positioned, which can be aspirated or biopsied.</td>
</tr>
<tr>
<td>Image-guided abdominal biopsy phantom</td>
<td>CIRS Tissue Simulation and Phantom Technology</td>
<td>This is suitable for training and demonstrating image-guided needle biopsy navigation tools or procedures that require a constant visual reference for needle placement. It is a self-healing phantom, allowing for multiple biopsy insertions with minimal needle tracking.</td>
</tr>
</tbody>
</table>

This is an exemplary list because many smaller companies may supply similar products.
the haptic feedback were comparable to that of human beings.\textsuperscript{[41–45]}

Since then, in vivo models have been used in training centers around the world, with a particular focus on endoscopic ultrasound-guided invasive biopsies (EUS-FNA) and interventions.

To train EUS-FNA, gastric or esophageal saline deposits were injected intramurally to imitate subepithelial tumors or mediastinal pseudo-lymph nodes.\textsuperscript{[46–48]} Ligresti et al.\textsuperscript{[49]} published the use of an in vivo porcine model for the training of the pancreaticobiliary system with a radial and longitudinal EUS scanner as part of a structured training program of the International School of EUS (WISE).

For training of EUS interventions, several publications describe porcine models, for example, for EUS-guided gallbladder drainage with a lumen-apposing metal stent,\textsuperscript{[50]} for dilatation of self-created benign biliary strictures,\textsuperscript{[51]} or models for improving the access route to the biliary system.\textsuperscript{[52]} Several techniques are mentioned to create a porcine biliary dilatation model like using endoscopic hemoclips, band ligation, argon plasma coagulation of the major papilla, and even laparoscopic ligation or over-the-scope clips (Ovesco, Tübingen, Germany).

Internal liver lesions as EUS-FNA targets in porcine models were implanted by using empty shells of iodine-125 seeds. In a training program with 10 trainees, the total procedure time for EUS-FNA decreased from step to step with significant improvement in the overall success rate.\textsuperscript{[53]}

Despite the realistic experience, live animal training must take into account the ethical principles and the local laws. The high costs and the animal organs with the need for the use of veterinary equipment limit the general use as routine training.\textsuperscript{[54]}

**Phantoms**

A simple phantom for training of EUS-FNA was first presented by Sorbi et al. in 2003.\textsuperscript{[55]} Olympus (Tokyo, Japan) uses various phantoms to train practitioners in gastrointestinal wall pathology and EUS-FNA. The “gut wall invasion” phantom is a simple model for depiction of subepithelial tumors or tumor invasion in correlation to the T-classification. The “EUS-FNA phantom” is a box with a central orifice that mimics the esophagus containing different types and sizes of silicone blocks to train the technique of EUS-FNA.\textsuperscript{[56]}

**Ex vivo or composite models**

So-called ex vivo models have been used in Europe since 1997 for endoscopy training. The best known is the Erlangen Active simulator for Interventional Endoscopy (EASIE), which was later presented in a more compact version as CompactEASIE.\textsuperscript{[45,57]} Most experiences with these models result from the classic endoscopic examinations, whereas there are only a few reports on the use in EUS. The main objective of this model is to learn endoscopic therapeutic interventions. Specially prepared, cleaned, and deep-frozen porcine organs of the upper and lower gastrointestinal tract as well as the biliary system are thawed approximately 5 to 6 hours before implantation and then fixed in a manikin or box as anatomically correct as possible. The Erlanger Endo Trainer consists of a head and torso that can be pulled into any position. The compactEASIE is restricted to the embedded organs within a simple box. The model can be modified for EUS training, but this requires additional preparation of the trainer itself and the “extra luminal structures” such as lymph nodes or cysts. To imitate extra luminal pathologies, for example, parts of the spleen as “lymph nodes” or pieces of small intestine filled with water as “pseudocysts” are placed around the gastrointestinal tract and fixed with sutures.\textsuperscript{[58,59]} Baron and DeSimio\textsuperscript{[60]} published an ex vivo pig model for EUS-guided training of transmural puncture with drainage of pancreatic cysts and fluid collections similar to the Erlangen Model.\textsuperscript{[60]} An ex vivo model for rectal US with a formalin-fixed porcine intestine and self-created “circular tumor” or “abscesses” is integrated into a transparent plastic box and can be used for 48 hours of training.\textsuperscript{[61]}

The advantages of the Erlangen Endo Trainer, the compactEASIE, or similar trainers are the simulation of EUS-FNA and the possibility of a modification for therapeutic interventions. That is why these models are used in many hands-on courses worldwide, and its benefits for improving the technical skills of the trainee are evident. The relatively long preparation time, the mobility of the organs despite embedding in gel or agar, the altered anatomy, and the lack of the characteristic echo morphology must be viewed as potential disadvantages. Ultrasound artifacts arise because of the autolysis, for example, in the liver and due air bubbles in the surrounding US gel.

Newer developments report the combination of a 3-dimensional (3D) printed dilated bile duct system together with an ex vivo liver model (so-called Mumbai EUS stereo lithography/3D printing bile duct prototype).\textsuperscript{[62]}

The Luebeck EUS Trainer is another new trainer for invasive and interventional EUS. It is a water-perfused closed case with 2 accesses to the upper and lower gastrointestinal tract. Pig organs are embedded into a bottom and lid matrix, which is suitable for US. Holes within the matrix close to the organs allow for the fixation of urinary bladders (“pseudocysts”), artificial puncture objects (“lymph nodes”), and an artificial “prostate.” The bladders are connected with flexible tubes and can be refilled via valves on one side of the case. They are fixed with clips to avoid a rotation during puncture (pseudocyst drainage). The model allows even the use of cautery devices and the placement of all kinds of stents, for example, expandable metal stents. To avoid any air artifacts, a continuous water level can be guaranteed via a water pump in the case and via a relief valve on the top cover. The case and the matrix are suitable for fluoroscopy and can be cleaned with standard disinfection. Because the organs are in a closed system filled with salt water and the bladders can be refilled, the case can be used for a full 1-day course.

**VR simulators and PC-based simulations**

Since the first computer-based or VR simulators for colonoscopy and endoscopic retrograde cholangiopancreatography in the early 1980s,\textsuperscript{[63]–[65]} the increasing progress in technology has led to a considerable improvement in the graphic depiction with a realistic representation of the gastrointestinal lumen. For an overview of the technical aspects of US simulation, we refer to part 1 of the state-of-the-art paper. A comparison of strengths and opportunities with weaknesses and threats of current VR simulation-based training is outlined in Table 3.

For EUS, basically 2 different techniques are important: interactive video technology and computer-graphic simulation (CGS).\textsuperscript{[63–66]} Interactive video technology is based on real endoscopic images that are stored on a videodisc and can be displayed in real time at the request of the user. Conversely, CGS is a simulation of graphic computer images that imitates original endoscopic images and also displays them on demand in real time.
VR: virtual reality.

Videographic technology combines both systems, with endoscopic images being overlaid with graphic images (eg, catheter). GI Mentor II (interactive video technology and CGS system; Simbionix Ltd, Lod, Israel) is the first commercially available VR simulator that includes an EUS application.\(^{[63,66–68]}\) The device consists of a mobile system with a torso, endoscope, a monitor, and a computer module. The US images of the EUS module are based on 3D computed tomography and magnetic resonance imaging scans. An algorithm allows for longitudinal and radial endosonography under real-time conditions. The module is integrated in a manikin, whereby a mock endosonography device is not used, and passage into the movements. A sensitive tracking system translates the position and scans direction into computer-generated images. It is possible to switch between endoscopic and EUS images. The monitor can display the transducer position of the sector in the 3D image and the associated 2D image at the same time. The additional functions include the designation of the anatomical structures, the depiction of the section plane, colored illustrations of the organs, zoom option, size measurement, reporting on the examination, and an evaluation of the examination results. By coloring anatomical structures, vascular structures and organs can be followed.\(^{[59]}\) The system includes various teaching modules, online help, and query options. However, mediastinal organs are not included in the system.

The Ikuma model is another newer EUS trainer. It was developed in cooperation with Olympus Medical Systems Cooperation (Tokyo, Japan) and Kyoto Kagaku (Kyoto, Japan). The model allows anatomical and some pathological structures for radial and longitudinal EUS at a very good quality, but the mediastinum is not included, and passage into the duodenum is not possible. The model is integrated in a torso so that the endoscopic maneuvers can be simulated within the stomach.\(^{[59]}\)

Recently, a Swiss company (Simedis) developed an EUS prototype in collaboration with a medical community for hands-on training of both linear and radial EUS. The simulation is based on pseudo-US. The device is equipped with an echoendoscope and 2 monitors. Further developments of the simulator will show whether the previous results of the anatomical structures can be improved.

Unfortunately, most of the other VR simulators that are used in endoscopic training do not have an EUS module.\(^{[56]}\)

PC- or Web-based EUS teaching programs must be distinguished from the aforementioned VR systems, as they can be installed on any laptop. The US transducer is controlled with a mouse, a keyboard, or a haptic handle. This results in limited movement options (degrees of freedom) and a less realistic experience. Advantages include reduced costs and mobile availability. It is a relatively easy way to learn basic skills including anatomy and image interpretation.

The simulation program “EUS meets Voxel-Man” implements the simulation of longitudinal endosonography on a multimedia DVD on the basis of the VOXEL-MAN 3D Navigator “Inner organs.”\(^{[71,72]}\) Other modules are connected via hyperlinks, so that interactive, multimedia use of the learning content is possible. In addition to the screen text, videos can be selected that integrate the VOXEL-MAN simulation into a normal examination. A newer version of the program is in development.

**CONCLUSIONS**

Ultrasound simulation is a key part of health professions education, without which doctors, other US practitioners, and patients would be moved backwards by decades to the years of the “see one, do one, teach one” approach to medical and US training. Simulation has been revolutionary as a training methodology across medicine and other health care settings, but the impact on US use may be especially significant. Because of a combination of rapid spread of point-of-care US and an ever-worsening shortage of trained instructors, simulation can provide the teaching extension required by tens of thousands of medical trainees, residents, fellows, sonographers, and other trainees around the world. One particular challenge is the training of practicing doctors and professors, in US, who may have limited available time and energy for learning a new modality. Nonetheless, US simulators are really in their infancy compared with the eventual tasks they will perform and that are asked of them. Further technological developments may enable artificial intelligence to be integrated into US simulators, with an algorithm that can track the trainee’s weaknesses and provide more focused, individualized training.

The time is now to embrace simulation-based training in INVUS, following well-established and evidence-based training curricula from other specialties. Training models are vast and are widely available—ranging from simple part-task trainers to VR simulators train interventional procedures. Although the evidence for some clinical specialties still lags in terms of how these translate
to the clinical environment, it is pertinent to ensure that the choice of simulation-based equipment is based on established trainee needs and the goals and objectives of training. Development and implementation of simulation-based training should be preceded by research with a focus on the quality of simulation performance feedback, the reliability and validity of simulation-based assessment instruments, and the transfer of skills from the simulation laboratory into clinical practice.

The aim in simulation-based training is to use the positive aspects of simulation systems for trainee-centered learning, offering a safe and consistent environment to enhance the learning experience and meet the curriculum learning outcomes, while reducing the impact on patient throughput.

**Conflicts of Interest**

Christoph F. Dietrich is a Co-Editor-in-Chief of the journal, and Adnan Saftoiu is an Associate Editor. This article was subject to the journal’s standard procedures, with peer review handled independently of the editors and their research groups.

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