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Abdominal POCUS Education for Clinicians: A Systematic Review of Teaching Methods for Point-of-Care Abdominal Ultrasonography

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ABSTRACT

This systematic review examines educational strategies in clinician-performed abdominal point-of-care ultrasound (POCUS), a critical skill with increasing relevance in medical care. Analyzing 28 studies, we highlight the strategies as well as advantages and disadvantages of various theoretical and practical components, including, for example, e-learning and simulation in training programs. The findings emphasize the necessity of blending various educational methods to enhance effectiveness and adaptability in training environments. Ultimately, robust training frameworks are essential to maximize diagnostic accuracy and improve patient outcomes in abdominal POCUS.

1 | Introduction

Abdominal point-of-care ultrasonography (POCUS) is a safe and non-invasive examination used to confirm or rule out various pathological and potentially life-threatening conditions with high diagnostic accuracy in the hands of competent operators [1–6].

While radiologists typically perform comprehensive diagnostic abdominal ultrasound examinations, including, for example, contrast-enhanced ultrasound for detailed diagnostics, clinician-performed POCUS focuses on specific clinical questions that can be promptly addressed in the clinical ultrasound examination during patient assessment. This approach holds promise for expediting patient management and patient flow, could benefit patient outcomes, and thus healthcare institutions in general [7].

Over the past decade, POCUS has rapidly evolved, particularly in emergency and intensive care medicine, owing to its ability to facilitate early diagnosis and improve patient outcomes [8–11]. However, for patients to benefit from the high diagnostic accuracies of POCUS, clinicians conducting the ultrasound examination must undergo adequate training and attain competency. Various training methods are available. These range from the traditional clinical apprenticeship model, where the trainee acquires knowledge and skills through hands-on experience under supervision from a competent ultrasound operator, to remote training programs utilizing simulation-based techniques. Each of these approaches presents unique advantages and disadvantages which must be taken into account when planning and implementing structured educational training programs in abdominal POCUS.

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There is, therefore, an increasing demand for training, understanding of the most optimal methods, and a need for evidence-based structured training programs to ensure high diagnostic accuracy, identification of illness, and for crafting good treatment plans benefiting patients.

This systematic review aims to examine the educational strategies employed in abdominal POCUS, compare the various training methods, and identify the respective advantages and disadvantages of each approach.

2 | Methods and Materials

2.1 | Study Setting and Search Strategy

The systematic review was prepared in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines [12] and was registered in the international database of Prospectively Registered Systematic Reviews of Health Related Outcomes (PROSPERO) before conducting the search (PROSPERO registration number: CRD42023463742). The three databases used for the systematic literature search were: Web of Science, Embase, and PubMed. The PRISMA checklist is provided in the appendix (Appendix S1).

The terms used for the search were: abdominal OR abdom* AND point of care OR pocus OR focused OR focused assessment with sonography for trauma OR FAST AND Education OR training OR teaching OR assessment OR competence AND Ultrasound OR Ultrasonic OR sonography, including MeSH terms. The full search string is available in Appendix S2. Records were managed in the reference tool EndNote X9 (Clarivate Analytics, Philadelphia, United States), and furthermore, the records were uploaded to the Internet-based software program Covidence (Veritas Health Innovation Ltd., Melbourne, Australia), where duplicates were removed and articles screened. The search was completed on September 20th, 2023.

2.2 | Eligibility Criteria

The research question was formed using the Patient-Intervention-Comparison-Outcomes framework (PICO), and the methodology was adjusted to suit the educational aspect of the review; see Table 1.

The inclusion/exclusion criterion for this systematic review was: original studies describing education and/or training (competence) in abdominal POCUS, including courses, training programs, simulation, and other methods for abdominal POCUS. Diagnostic accuracy studies were excluded unless they also included outcomes that assessed or evaluated education, teaching, training, and/or competence in abdominal POCUS. Description of the education must be thorough, that is, it must be described how long the course/education lasted, possibly content/syllabus, whether it was divided into theoretical and/or practical training, and so on. Due to the aim of our study, studies that focused only on teaching normal anatomy, for example, the use of ultrasound for anatomical classes for medical students that did not focus on any pathology were excluded.

Highly detailed diagnostics such as pathological changes in the liver, intestines, and so on that require radiologist or other specialized expertise were also excluded. Participants must be doctors, clinicians, residents, and/or medical students outside the radiology speciality, nurses, nursing students, or EMTs. Studies involving radiology residents/radiologists were excluded because radiologically performed abdominal ultrasound examinations exceed the focused questions posed in abdominal POCUS, and they are expected to have a higher training and knowledge level.

Veterinarians were also excluded. All included studies must be original papers, available in English, published, and available in full text. Reviews, commentaries, and letters were excluded.

2.3 | Selection Process

After removing duplicates, the identified results were screened independently by two authors (B.Ö.S. and Ó.K.Þ.). First, the articles were screened by title and abstract, and second by full text with a focus on the keywords of the search (abdomen, education/teaching/training, and FAST/POCUS/ultrasound) to assess their eligibility for inclusion in the study. Conflicts were settled by a third author (P.I.P.).

2.4 | Risk of Bias

The risk of bias in each included article was assessed and determined using the Medical Education Research Study

TABLE 1 | PICO model of research question.

Participants/population	*Doctors, clinicians, residents, medical students, nurses, nurse students, Emergency Medical Technicians (EMTs)*
Intervention	Teaching and training methods of abdominal POCUS
Comparison	*Comparison of the different teaching and training methods of POCUS (e.g., simulation training* vs. *clinical training, theoretical* vs. *practical training, assessment/test* vs. *other evaluations, e.g., clinical, etc.)*
Outcomes	Compare the various methods of abdominal POCUS teaching and training for medical personnel outside the radiology speciality, and respectively identify advantages and disadvantages.

Quality Instrument (MERSQI) and the Newcastle-Ottawa Scale–Education (NOS-E) assessment tools [13]. These quality assessment instruments are widely used to appraise the methodological quality of medical educational studies. As they both are made for but do not individually cover all the aspects of medical educational research, both tools were chosen.

3 | Results

3.1 | Search Strategy

The systematic search was performed on September 20th, 2023, and yielded 4926 publications in the three databases. A total of 1390 duplicates were removed, out of eight manually; thus, 3536 were screened by title and abstract. Of these, 3386 studies were excluded. Thus, studies that assessed for eligibility were 150. After the exclusion of 122 studies, a total of 28 publications were included in the current study and synthesis. A detailed overview of the eligibility process can be found in the PRISMA flowchart in Figure 1.

3.2 | Study Design

Of the 28 publications that were reviewed, there were 19 pre-test and post-test studies [14–32]. Three of the pre-test and post-test studies had a follow-up time from 2 weeks to 18 months, an average of 17 weeks [14, 24, 28]. There were five post-test-only studies [33–37]. Three diagnostic accuracy studies [38–40]. One study was purely a prospective observational study [41]. Study characteristics are presented in Table 2.

3.3 | Assessment

Of the 19 pre- and post-test studies, 18 used written and/or multiple-choice questions to assess theoretical knowledge

FIGURE 1 | Flowchart of search strategy, and selection process based on the preferred reporting items for systematic reviews and meta-analysis.

TABLE 2 | Publications on education in lung ultrasound: Study characteristics.

	Study design	Assessment	Abdominal US focus	Duration	Education tool	Participants
Pre-test, post-test educational studies						
Press et al. [30]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test MCQs **Practical**: Observational using assessment tools, OSCE	Free fluid or ascites (FAST/eFAST)	2 months	4 h didactic lectures, pocket flashcards, six Internet-based educational modules, 4 h hands-on training on patients, supervised scanning in the emergency department, experiential practice on the helicopter, a review session, and remedial training	33 Helicopter paramedics and flight nurses of a critical care air medical transport service
Karagöz et al. [29]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, same 25 questions for both tests **Practical**: Check list	Aorta, kidney, free fluid or ascites (FAST/eFAST), gallbladder, liver	2 days	5.5 h didactic lectures and 6 h hands-on training with healthy volunteer and interactive session using a web-based simulation, case scenarios and healthy volunteers	40 physicians, of which 20 emergency physicians, 15 anesthesiologists, 2 pediatric emergency physicians, 2 general practitioners and 1 pediatrician
Eroglu et al. [32]	Pre-test, post-test educational	**Theoretical:** Pre- and post-test, same 20 MCQs for both tests **Practical**: Observational using assessment tools	Free fluid or ascites (FAST/eFAST)	4 weeks	4 h didactic on basic physics and knobology, FAST/eFAST, rapid ultrasound for shock and hypotension, 16 h hands-on training using Sonosim ultrasound training solution device.	96 final year medical students
Toledo et al. [28]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, 15 MCQs **Practical**: Observational Follow-up test 2 weeks after the skills training	Free fluid or ascites (FAST/eFAST)	2 days	1 h of didactic lecture and 3,5 h of hands-on training on healthy models and in patients treated with peritoneal dialysis with different amounts of dialysate in their cavity	31 undergraduate medical students
Sekiguchi et al. [27]	Pre-test, post-test educational	**Theoretical:** Web-based pre-test consisting of 43 MCQs **Practical**: Post-test, observational using assessment tools	Aorta, kidney, free fluid or ascites (FAST/eFAST), gallbladder, liver, urine bladder	1 day workshop, (access to Internet-based educational modules 1 week prior to hands-on training)	1.5 h Web-based didactic lectures (time spent unknown) and 1 h hands-on simulation training with focus on of the abdominal organs, detection of peritoneal fluid, and a focused abdominal sonography for trauma (FAST) examination	23 physicians

(Continues)

TABLE 2 | (Continued)

	Study design	Assessment	Abdominal US focus	Duration	Education tool	Participants
Schnobrich et al. [26]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, MCQs **Practical**: Observational using assessment tools	Free fluid or ascites (FAST/eFAST), urine bladder, IVC/aorta diameter	5 days	Theoretical teaching, hands-on training, web-based modules, scanning models, procedural simulators, and ultrasound simulators, in total 30 h	30 first-year internal medicine interns and 2 internal medicine-dermatology interns
Ramsingh at al [25]	Pre-test, post-test educational, RCT	**Theoretical**: Pre- and post-test, MCQs **Practical**: Observational	Free fluid or ascites (FAST/eFAST)	1 day	Didactic group: 1,5 h didactic based lecture Model/simulation group: 1,5 h interactive hands-on session in a simulation center	20 anesthesiology residents were randomized in to 2 groups, 10 in didactic group and 10 in a model/simulation group
Dinh et al. [24]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, Written test with 50 questions. 3-month follow-up test, Written with 50 questions **Practical**: Observational using assessment tools, simulation-based	Aorta, kidney, free fluid or ascites (FAST/eFAST), gallbladder, liver	2 days	8 h didactic lectures and live demonstration 8 h hands-on session on live healthy model and case training using an ultrasound simulator	8 ICU fellows/surgical ICU fellows
Shokoohi et al. [23]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, 20 questions **Practical**: Observational	Kidney, free fluid or ascites (FAST/eFAST) gallbladder, liver, urine bladder	1 day	45-min didactic lecture and 1 h hands-on training with a healthy volunteer	68 medical students
Zago et al. [22]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, MCQs	Aorta, kidney, free fluid or ascites (FAST/eFAST), gallbladder, intestines	Four 1-day modules: eFAST, USED, IUS, AVUS	For each module: Online training (time spent unknown), 1 h theoretical lecture and 4 h hands-on practice on healthy volunteer and interactive discussion of real clinical scenarios	416 doctors from 29 countries. They were 82% Surgeons, 16% Emergency Physicians or Intensivists, 2% other specialists. Residents accounted for 56% of participants
Juo et al. [21]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, 71-question written, the pre- and post- test were identical **Practical**: Observational	Free fluid or ascites (FAST/eFAST)	1 day	1 h didactic lecture. Group 1: Hands-on training with live patients models 1 h Group 2: Hands-on training with simulation models 1 h	29 general surgery residents split in two groups

(Continues)

TABLE 2 | (Continued)

	Study design	Assessment	Abdominal US focus	Duration	Education tool	Participants
Haghighat et al. [17]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, MCQs	Kidney, urine bladder	28 days	6 h didactic lectures and 18 h hands-on training at a simulation center and by performing scans on one another	40 postgraduate Internal medicine residents
Dornhofer et al. [20]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, MCQs **Practical**: Observational using assessment tools	Aorta, free fluid or ascites (FAST/eFAST), gallbladder, intestines, IVC/aorta diameter	4-week	6 session every 3–4 days each session included 1 h of theoretical training and then hands-on training for 3 h on healthy volunteer	19 physicians, 13 nurses and 19 midwives
Coiffier et al. [19]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, MCQs **Practical**: Observational	Kidney, gallbladder, liver	1 day	E-learning platform (time spent unknown) 1 h theoretical lecture on ultrasound imaging and 3 h hands-on training session on healthy volunteer and simulation training with radiologists	221 medical students in their 6th semester
Chen et al. [18]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, not described	Aorta, free fluid or ascites (FAST/eFAST), gallbladder, liver, intestines	12 sessions over 1 year	1 h lectures and 1 h hands-on practice	16 emergency medicine residents
Ferre et al. [16]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, 10 question MCQs	Aorta	4 months (1 session each month)	E-learning platform (time spent unknown) of 5 modules. 4 h hands-on training in scan lab	24 Residents from internal medicine, family medicine, emergency medicine and medicine/pediatric
Yamada et al. [15]	Pre-test, post-test educational	**Theoretical**: Pre- and post-test, MCQs	Free fluid or ascites (FAST/eFAST)	2 days	2-day course with theoretical lectures and hands-on using live models.	33 Nurse practitioners and Nurse practitioner trainees
Post-test only educational						
Salen et al. [33]	Post-test only educational	**Practical**: Ultrasound interpretation skill test—Observational	Free fluid or ascites (FAST/eFAST)	1 day	1 h didactic lecture (both groups) Group 1: Ultrasound simulator model—3 h practical practice on ultra-sim Group 2: Peritoneal dialysis model—3 h practical practice on peritoneal dialysis patients	20 EM resident physicians and 10 emergency medicine physicians

(Continues)

TABLE 2 | (Continued)

	Study design	Assessment	Abdominal US focus	Duration	Education tool	Participants
Afonso et al. [34]	Post-test only educational	**Practical**: Observational using assessment tools, OSCE	Aorta, free fluid or ascites (FAST/eFAST)	1 day	3 h theoretical lecture and 2 h hands-on session bedside with standardized patients	307 s-year medical students
Andrea et al. [37]	Post-test only educational	**Practical**: Observational using assessment tools, OSCE	Free fluid or ascites (FAST/eFAST)	1 day	4 h of theoretical lecture on ultrasound physics, semantics, artifacts on images and dynamic video tape 4 h Hands-on sessions on patients with or without ascites	5 residents in gastroenterology or internal medicine
Guy et al. [35]	Post-test only educational	**Theoretical**: Written examination, 30 questions MCQs and written questions **Practical**: Observational using assessment tools	Free fluid or ascites (FAST/eFAST)	2 days	Prereading modules built from online resources (time spent unknown) and 4 h didactic lectures and 8 hands-on training on healthy models	17 Critical care paramedics
Britz et al. [36]	Post-test only educational	**Practical**: Observational using assessment tools, OSCE	Free fluid or ascites (FAST/eFAST)	3 weeks	Both groups 30 min theoretical introduction per participant. See one, do one group had 1 h of hands-on training. Mastery learning group 1 h hands-on training	146 medical students in their fourth year. Two groups see one, do one or mastery learning.
Diagnostic test accuracy studies						
Jang et al. [38]	Diagnostic test accuracy study	**Practical**: Observational **Other**: Post-curriculum image interpretation, RDMS reviewed ultrasound images	Upper quadrant ultrasound examinations, gallbladder	2 days	4 h lecture with demonstration and 2 h hands-on training on healthy models	13 Residents
Elliott et al. [39]	Diagnostic test accuracy study	**Other**: Post-curriculum image interpretation	Aorta, kidney, free fluid or ascites (FAST/eFAST)	4 half-day workshop over 1 year	2 to 3 h workshop with 30 min lecture/demonstration and 2.5 h hands-on training in simulation lab	19 internal medicine residents
Torres-Macho et al. [40]	Diagnostic test accuracy study	**Other**: Post-curriculum image interpretation by department of radiology	Kidney, gallbladder	2 days	5 h theoretical lectures and 5 h hands-on training on healthy models	5 attending emergency physicians

(Continues)

TABLE 2 | (Continued)

	Study design	Assessment	Abdominal US focus	Duration	Education tool	Participants
Other studies						
Chalumeau-Lemoine et al. [41]	Prospective, observational study	**Other**: Observational assessment by department of radiology	Kidney, free fluid or ascites (FAST/eFAST), gallbladder, liver, urine bladder	1 day	2.5 h didactic lecture and 6 h hands-on training in radiology department (the residents performed 73 examinations on real patients under supervision during the study period)	8 ICU residents
Young et al. [14]	Prospective, observational study, Pre-test, post-test	**Theoretical**: Pre- and post-test, MCQs **Practical**: Observational using assessment tools, Assessment of knowledge, skill follow-up at 6 months, 12 months, and 18 months after the first training session	Aorta, free fluid or ascites (FAST/eFAST)	2 one-day sessions with 6 moths between and maintenance session every week for 1 year	4.5 h didactic lectures and 4 h hands-on training on healthy volunteers and 52 1 h maintenance sessions	22 pulmonary and critical care medicine fellows
Bhargava et al. [31]	Pre-test, post-test educational and curriculum development (Kern)	**Other:** Pre- and post-self-reported measures	Free fluid or ascites (FAST/eFAST), urine bladder	7 weeks	Ones per week 45 min didactic lecture and 1 h hands-on training session on standardized patients	7 pediatric critical care fellowship trainees

Abbreviations: AVUS = Advanced Visceral Ultrasound; eFAST = Extended Focused Assessment with Sonography in Trauma; FAST = Focused Assessment with Sonography in Trauma; ICU = Intensive Care Unit; IUS = Interventional Ultrasound; MCQs = Multiple-Choice Questions; OSCE = Objective Structured Clinical Examination; RDMS = Registered Diagnostic Medical Sonographer; USED = Ultrasound in Emergency Department.

[14–30, 32], of which four evaluated theoretic knowledge solely [15–18].

Twelve studies included both objective assessments of theoretical knowledge and practical competencies [20, 21, 23–30, 32, 39]. Whereas one relied on self-reported measures [31].

Four of the five post-test-only studies assessed practical competencies solely [33, 34, 36, 37], and one assessed both theoretical knowledge and practical competencies [35].

Three studies used post-curriculum image interpretations as an assessment where participants performed scans on patients [38–40]. Images were then saved, sent to, and reviewed by an experienced radiologist for assessment and feedback. One used observational assessment where a patient was scanned by the trainee and the assessor would observe and supervise while asking one or more predetermined questions regarding the examination [41].

3.4 | Duration and Educational Strategy

The duration of educational programs ranged from a 1-day workshop to 12 sessions over 1 year. Most studies ($n = 17$) included 1–2 day workshops with 4–8 h of daily practice. None of the studies had modules varying in hours with regular intervals lasting from 3 weeks to 12 months.

All studies combined theoretical and hands-on training with varying total hours and training methods. Theoretical training ranged from 30 min [36, 39] to 8 h [24]. One study found better results with lectures in a simulated setting versus traditional lectures using a randomized study [25]. Two studies used an e-learning platform for the theoretical content, allowing flexible time for lectures [16, 27]. Three studies (11%) involved pre-course e-learning, where the trainees had access to online theoretical training before conventional lectures; however, the total time spent was unknown [19, 22, 35].

Hands-on training ranged from 1 h [23] to 30 h [26] with different training methods. Twelve studies (43%) involved healthy simulated patients, 10 studies (36%) involved phantom simulation training, and 8 studies (29%) involved live patient training.

Coiffier et al. combined both healthy simulated patients and phantom simulation training [19]. Two studies randomized trainees to either training on live patients with pathology or on a simulator [21, 33]. One found simulation to be a valid training method, but with lower assessment scores, concluding that simulation cannot stand on its own and may not replace training in a clinical setting. The other found the methods equal.

One study compared the "see one, do one" training and mastery learning, being the only study involving either one of those training methods [36]. Chen et al. did not describe the method used in hands-on training [18] and Yamada et al. did not state the total hours of hands-on training [15].

3.5 | Abdominal Focus

The review comprised 28 studies, all centered on point-of-care scanning of the abdominal cavity. Predominantly, the use of ultrasound for diagnosing free abdominal fluid and ascites, or the use of Focused Assessment with Sonography in Trauma (FAST)/

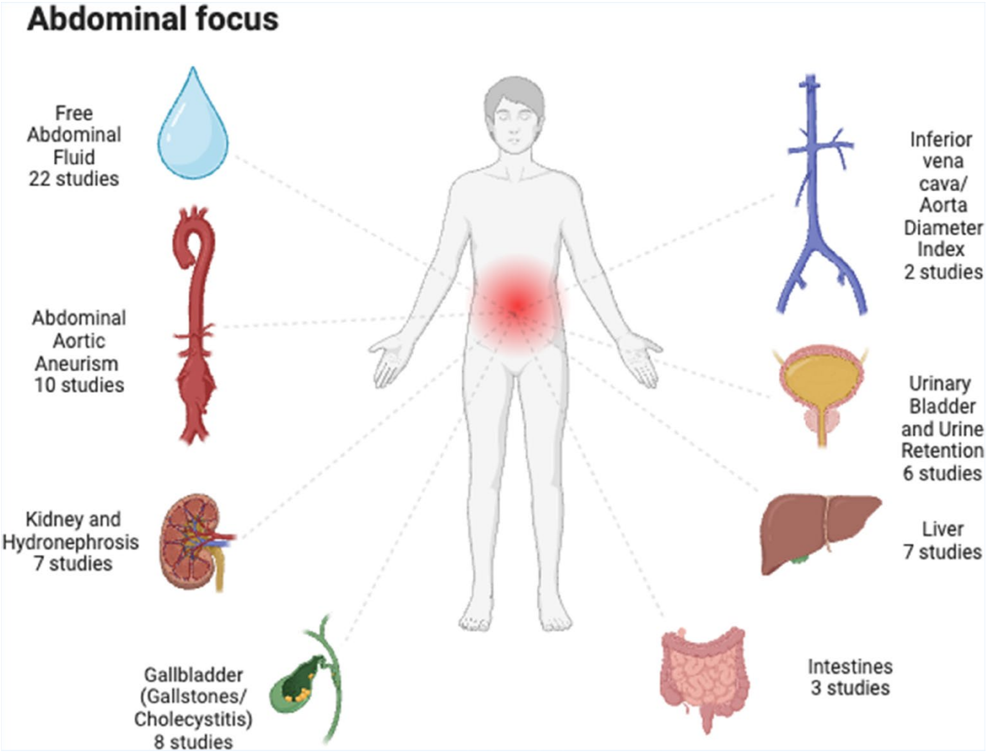

FIGURE 2 | Abdominal focus of included studies. *Source:* Figure created with www.BioRender.com.

TABLE 3 | Summary of included studies mentioned advantages and disadvantages of the different educational strategies.

Educational tool	Advantages	Disadvantages
Theoretical		
Online learning for theoretical purpose [16, 19, 22, 23, 30, 35]	Online teaching modalities provide advantages emphasizing the feasibility and flexibility of internet-based training. Participants can conveniently pace their learning and access content at their convenience. Online prereading modules support self-directed learning, enabling students to prepare for courses on their schedules. The integration of e-learning enhances the overall experience, providing accessible resources. Full access to post-training e-learning platform facilitates skill consolidation.	Web-based learning alone is not sufficient for achieving proficiency in image acquisition. Relying solely on participant self-control can lead to variations in the depth of understanding among participants. Online training might reduce personal interaction, impacting student engagement and real-time feedback. The feasibility of the training depends on the reliability of technology, and technical issues may disrupt the learning process.
Traditional theoretical strategies (textbook learning, didactics) [23, 29, 39]	Are cost-effective, requiring fewer resources and are suitable for large cohorts of learners, making it scalable for broader audiences. They are familiar and easy to implement, requiring minimal specialized equipment or facilities.	Lack of hands-on practical application, potentially resulting in a gap between theoretical knowledge and proficiency. Less engaging for learners. May cover vast information in a short time, leading to information overload and hindering deep understanding.
Practical		
Simulation-based training and live patients with pathology in a non-clinical setting [15, 22, 25, 28, 32, 33]	Simulation-based training offers flexibility, available at any time for students to practice and enhance their skills without constraints and disruptions by clinical work and flow. This flexibility contributes to repeated practice, reducing shyness, increasing confidence, and improving the speed of evaluation. Simulators can offer a broad range of sonographic findings and pathology, enhancing the trainee's exposure. Practical exposure through simulation-based training contributes to enhanced technical proficiency in performing ultrasound examinations and allows for a controlled and standardized learning environment, ensuring consistent training experiences. Peritoneal dialysis models closely resemble the sonographic appearance of hemoperitoneum, providing a realistic simulation for trainees. Peritoneal dialysis models allow trainees to evaluate human models with varying amounts and of intraperitoneal free fluid.	The cost of simulators, maintenance, and the need for technical and software upgrades may pose financial challenge. Implementing a model/simulation-based education strategy may require significant resources and may be logistically challenging compared to traditional teaching strategies. They do not entirely replicate the experience of scanning a live human. Controlled scenarios may limit exposure to the full variability of real clinical settings. Peritoneal dialysis models may not fully simulate the challenges of diagnosing free intra-abdominal fluid in a clinical setting (FAST/eFAST), potentially affecting the transferability of skills. Peritoneal dialysis models may exhibit non-standard anatomy, such as atrophic bladders and kidneys, limiting their representativeness. Frailty of peritoneal dialysis models, stemming from co-morbid conditions, may affect their availability and suitability as training models.
Healthy simulated patient [20, 24, 25, 28, 29, 35, 38, 40]	Suitable for anatomical and topographical studying that present unique challenges, and certain nuances in anatomy that can be difficult to simulate. Allows learners to build confidence in their abilities before dealing with complex medical cases. Healthy models are readily available and do not require medical supervision, making them an efficient resource for training programs. Peers who volunteer as models may offer more flexibility in scheduling training sessions.	The focus on a healthy model with no pathological findings might not adequately prepare participants for scenarios involving real patients with diverse pathologies. Healthy models may struggle to authentically reproduce the emotional responses of patients facing serious health issues.

(Continues)

TABLE 3 | (Continued)

Educational tool	Advantages	Disadvantages
Approach		
Mastery Learning approach [36]	Mastery learning involves a structured progression through different levels of competency, with each level requiring verification by the trainer. This structured approach provides a clear pathway for skill development, ensuring that students master each skill before progressing to the next level. This is effective in ensuring that students achieve a more comprehensive set of competencies. This helps minimize achievement gaps by ensuring that all students, regardless of their initial level, reach a predetermined level of proficiency. Mastery learning involves continuous assessment, offering students immediate feedback on their performance, allowing them to correct mistakes and solidify their understanding.	The mastery learning approach, with its emphasis on achieving specific competencies before progressing, may be more time-consuming compared to other traditional approaches. This could be a limitation, especially in educational settings with time constraint. It often demands more resources, including additional instructional materials, personalized support and technology.
"See one, do one" approach [36]	This approach is time-efficient, making it suitable for scenarios where time is limited. Learners can swiftly move from observation to practice, optimizing the use of available learning time. This method facilitates quick skill acquisition by providing a visual demonstration followed by immediate hands-on practice.	The "See One, Do One" approach may not accommodate the individual learning pace and needs of each participant. Some learners might need more time for observation or practice, leading to potential gaps in understanding. Rapid transition from observation to action may limit learner's opportunities for reflection and feedback.

extended FAST techniques, was the most frequent with 22 studies [14, 15, 18, 20–32, 34–37, 39, 41]. Among these, 10 studies focused only on free abdominal fluid, ascites, or FAST/eFAST [15, 21, 25, 28, 30, 32, 33, 35–37].

Aorta and abdominal aortic aneurysm (AAA) were the included focus of 10 studies [14, 16, 18, 20, 22, 24, 27, 29, 34, 39]. Focus on the inferior vena cava/aorta diameter index in the assessment of the body fluid status was included in two studies [20, 26]. Kidney and hydronephrosis were among the included focus of seven studies [17, 19, 22–24, 27]. Focus on gallbladder (8) was included in eight studies [18–20, 22–24, 27, 29]. Focus on liver pathology was included in seven studies [18, 19, 23, 24, 27, 29, 41]. Focus on urinary bladder and urine retention was included in six studies [17, 23, 26, 27, 31, 41], and focus on intestines was included in three studies [18, 20, 22]. Summarized in Figure 2.

3.6 | Participants

Most study participants were medical students, varying from second-year to final-year students. The group of residents/fellows covered a large spectrum, where participants were, among others, first-year internal medicine interns, anesthesiology residents, ICU fellows, general surgery residents, emergency medicine residents, or participants from various internal medicine and family medicine sub-specialities. The physician group included a broader category of doctors from 29 countries, with a majority being surgeons, emergency physicians, or intensivists. Participants from other specialities included groups of nurses, nurse practitioners, midwives, and critical care paramedics, see Table 2.

3.7 | Advantages and Disadvantages

Extracted and summarized advantages and disadvantages of the different educational strategies from the studies are presented in Table 3, and are discussed in the discussion section.

3.8 | Quality Assessment and Risk of Bias Assessment

The MERSQI was applied to all 28 included studies; the highest score obtained was 14.5 [30] and the lowest was 9 [39]. The average score was 11.9. Newcastle-Ottawa Scale-Education (NOS-e) was applied to all 28 studies; the highest score was 4 [25] and the lowest 1, which was obtained by three studies [14, 27, 39]. The average NOS-e score was 2.1. Table 4 contains summarized MERSQI and NOS-e scores for individual studies; in Supporting Information S1, the MERSQI and NOS-e checklist for individual studies.

4 | Discussion

This systematic review aimed to explore the educational strategies in abdominal POCUS and highlight the included studies' advantages and disadvantages of the various methods. All 28 studies included reported a positive impact on the trainees' point-of-care ultrasound competencies as a result of their educational intervention; however, it was not possible to compare the various training methods as no studies explored various training methods head-to-head. First, the study designs and subsequently, the educational strategies are discussed, and last a section on future perspectives is found below.

TABLE 4 | MERSQI score and NOS-e score for individual studies.

	MERSQI	NOS-e
Press et al. [30]	14.5	2
Karagoz et al. [29]	13	3
Eroglu et al. [32]	12	2
Toledo et al. [28]	12.5	2
Salen et al. [33]	12	3
Jang et al. [38]	11	2
Chalumeau-Lemoine et al. [41]	13.5	2
Afonso et al. [34]	11	2
Sekiguchi et al. [27]	11.5	1
Torres-Macho et al. [40]	13	2
Schnobrich et al. [26]	13	2
Ramsingh et al. [25]	10.5	4
Dinh et al. [24]	11.5	2
Shokoohi et al. [23]	11	2
Zago et al. [22]	12	3
Juo et al. [21]	11	2
Andrea et al. [37]	13.5	2
Guy et al. [35]	13	3
Dornhofer et al. [20]	12.5	2
Coiffier et al. [19]	11	2
Britz et al. [36]	11	2
Chen et al. [18]	10.5	2
Haghighat et al. [17]	11	2
Young et al. [14]	9	1
Ferre et al. [16]	14	2
Bhargava et al. [31]	14	2
Yamada et al. [15]	12.5	2
Elliott et al. [39]	9.5	1

Abbreviations: MERSQI = Medical Education Research Study Quality Instrument; NOS-e = Newcastle–Ottawa Scale-Education.

4.1 | Study Designs

The predominant study design in the abdominal POCUS educational literature reviewed involved a single-group, pre-test, and post-test assessment design. This educational study design provides baseline as well as postinterventional measurement of skills and thereby allows comparison within the same group, reducing the impact of individual differences [42]. However, despite being commonly used, this method suffers from critical limitations. First of all, it induces the potential of the testing effect, meaning that the pre-test may influence the trainees' focus and performance on the educational intervention, and thereby, the accuracy of the improvement measurement. It also suffers from limited generalizability, as the findings and setup might not broadly be transferable to another context or trainee population. As the aim of this systematic review was also to compare the various educational methods, these studies lack a comparison group, and by conclusively using the single-group, pre-test, and post-test assessment design, it is not possible to answer whether one method is more efficient than another. None of the included studies described, explored, or referred to validation of the included assessment tools, which is of crucial importance to ensure that the test actually measures what it is supposed to measure [43].

Multiple included studies have highlighted that a specific educational method is better than no education. In other words, when trainees undergo an educational intervention, their post-test scores will improve in comparison to having no educational intervention. These studies do not contribute to understanding the true impact or effectiveness of specific educational interventions [44–46]. If studying one educational method towards another, a randomized trial is preferable and was done in few included studies [21, 25, 33, 36]. A set-up conducting a randomized controlled trial on two different training or educational methods requires more practicality and costs, which could be the reason why not that many randomized controlled trials were identified. Randomization in medical educational research naturally increases the level of evidence and validity. However, when comparing one intervention to another in terms of knowledge enhancement or increasing practical competency, it provides minimal insights into the specific components of the intervention responsible for the observed improvements.

4.2 | Simulation-Based Training Versus Real Patients or Simulated Patients

Simulation-based training can be valuable in many ways when it comes to teaching POCUS. We found that simulation offers flexibility, enhances skills without constraints, and increases confidence in practical skills. Simulation, independent of it being in a simulation center with a mannequin and software, or, for example, head-mounted virtual reality, creates a calm and safe learning environment without interruption by clinical work or flow. Using simulation, it is possible to train high-risk procedures or ultrasound examinations on "critical patients" without compromising real patients' safety. Simulation is more efficient when combined with other methods as a part of a structured program with clear learning objectives and cannot stand solely on its own [47]. In ultrasound, even though it can enhance the trainees' skills, correct techniques, working the probes correctly, and learning basic locations of common anatomical landmarks, simulation does not entirely replicate the experiences of scanning patients or simulated patients, and additionally, controlled scenarios may limit exposure to the full variability of real clinical settings with real patients. Furthermore, the cost of simulators, maintenance, and the need for technical and software upgrades may pose a financial challenge. Implementing a model or simulation-based training in an educational training program requires a structured and well-designed approach [48].

Another method described in the included studies is the use of healthy simulated patients or volunteers. In this case, it can be either the trainees themselves who practice POCUS on each other or volunteers, thus making them an efficient resource for training programs despite also requiring resources to invite and coordinate healthy volunteers. Healthy volunteers are beneficial for learning POCUS because they are suitable for anatomical and topographical study; however, it is not possible to simulate sonopathology. Thereby, one could include pathological ultrasound clips on a laptop next to the simulated patient to make the training case-based.

The method gives trainees confidence in the technical and practical competencies of ultrasound examinations using real ultrasound machines before dealing with complex medical cases and being around patients. On the other hand, like with the simulation, this method might not adequately prepare participants for scenarios involving real patients with diverse pathologies. An approach could be to train the practical techniques on simulated patients and learn about pathology using theoretical cases, including real-time images and ultrasound clips. Like with the simulated training, using healthy models can be very beneficial in POCUS training programs if used correctly [20, 24, 25, 28, 29, 35, 38, 40].

4.3 | Mastery Learning and the Use of Assessment

Mastery learning involves a structured progression through levels of competence, advocating that all trainees are able to learn a skill or competence to proficiency, but focusing on that individual trainees have different learning paces and different needs of supervision or guidance, with each level requiring verification by the supervisor [49]. This structured approach provides clear learning outcomes and clear pathway for skill development, ensuring that trainees master each skill before progressing to the next level. This method includes continuous assessment, offering trainees immediate feedback on their performance, allowing them to identify gaps and solidify their understanding. Britz et al. [36] compared the conventional "see one, do one" approach and mastery learning, in the post-assessment, the mastery learning trainees outperformed those in the "see one, do one" group, indicating that the mastery learning approach is effective in achieving the desired learning outcomes. This corresponds to various evidence on the topic advocating mastery learning [50–52].

However, the time used for training could differ between the two strategies, making it not completely a comparable design. Additionally, the mastery-learning approach requires more resources and coordination. It is more costly, time-consuming, and requires a structured training program with tests or assessments with proven validity evidence to ensure that the test actually measures what it is set out to measure. Mastery learning could, on the other hand, also decrease the need for supervision by an experienced operator because a procedure has been trained in the simulated setting and some simulators can provide feedback and supervision [53]. The participant demographics in the reviewed studies varied, encompassing a diverse range of medical professionals, from medical students to residents in internal medicine interns, anesthesiology residents, ICU fellows, general surgery, and emergency medicine, among others, from 29 different countries. Furthermore, other health care professions such as nurses, nurse practitioners, midwives, and EMTs were also represented, concluding that POCUS can be managed by a broad range of healthcare personnel. There is evidence to support the achievement of competency by other healthcare professionals, equal to physicians [54], which could indicate that it could be more cost-efficient to create one multidisciplinary training program including different healthcare groups and medical specialties, instead of creating one course per subgroup or personnel group.

4.4 | Future Perspectives

The overall gap in the literature on this topic of abdominal POCUS education is the transfer of skills from the simulated setting to the patient-related setting. The question is whether an educational intervention positively affects clinical and patient-related outcomes [55]. Medical educators work to increase patient treatment, flow, and safety; however, many things affect these parameters, making it hard to correlate the medical educational intervention to a patient-related outcome [56]. Zendejas et al. found in a systematic review a small to moderate patient benefit but also questioned the bias and heterogeneity of the studies [57].

For the medical educational researcher, more evidence is needed comparing the different training methods head-to-head, subsequently exploring the transfer gap into the clinical setting. Studies have shown a gap when transferring skills learned in an educational setting into a clinical setting [58]. It is important to identify to which level the skills are transferred, what affects the transfer, and how we in the future can decrease this gap.

For an educational stakeholder in abdominal POCUS ultrasound, it is important to have a structured approach to curriculum development and to consider the advantages and disadvantages of the various training methods. The authors recommend following dedicated frameworks, for example, Kern's six-step approach for curriculum development, starting with a needs assessment, continuously establishing learning objectives, choosing training methods, and evaluating both the trainees and even as important the course itself [59]. The current systematic review can provide the stakeholder with the relevant literature on abdominal POCUS and knowledge, advantages, and disadvantages of the explored training methods.

5 | Conclusion

In conclusion, we examined the educational strategies employed in the published literature on abdominal POCUS education. We highlighted the advantages and disadvantages of the explored training methods and can conclude that a thoughtful integration of training methods is important when developing a POCUS course or training program.

Acknowledgments

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.