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RESEARCH

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General practitioners' scanning competence following tailored ultrasound training: a hybrid effectiveness-implementation study

Camilla Aakjær Andersen[1*], Søren Lundbye-Christensen[2], Allan Riis[1,3], Ulrike Mehnert[1], Thomas Løkkegaard[1], Troels Mengel-Jørgensen[1], Liv Dyre Rasmussen[1], Nicolai Soll[1], Bo Stork[1], Søren Kæseler Andersen[1], Louise Pil[1], Christian Stjernebjerg[1], Ole Graumann[4] and Martin Bach Jensen[1]

Abstract

Background As an imaging modality, ultrasound relies on user skill and demands the integration of anatomical understanding, image acquisition techniques, and clinical knowledge. Proficiency in performing Point-of-Care Ultrasound (POCUS) examinations is a gradual process necessitating ongoing practice and exposure. Office-based general practitioners (GPs) encounter distinctive educational challenges when striving to acquire and sustain scanning competences. Therefore, traditional short workshops and training programs are not well suited for GPs.

This hybrid effectiveness-implementation study aimed to explore whether a novel educational program, specifically tailored to meet the learning needs of office-based GPs, could lead to scanning competence by the program's conclusion and if this competence can be sustained post-course.

Methods GPs working in office-based general practice in Denmark were invited to participate in a three-months ultrasound educational program. To assess its effectiveness, participants underwent scanning competence evaluation by external experts at the end of the training program and again three months later. The experts assessed the participants twice using the objective structured assessment of ultrasounds skills (OSAUS) standardized evaluation tool. This evaluation covered seven items: 'indication for the examination', 'applied knowledge of ultrasound equipment', 'image optimization', 'systematic examination', 'interpretation of images', 'documentation of the examination', and 'medical decision-making'. To evaluate implementation of the educational program, data were collected on the participants' completion of the program's educational elements and their use of POCUS following the program.

Results The 18 participating GPs were found to have scanning competence scores after completing the educational program, ranging from 68.9% to 82.3% of the maximum score, depending on the POCUS application. At follow-up, their scores had significantly increased for all POCUS applications, ranging from 80.9% to 92.6% of the maximum score. While completion of the educational elements varied between participants, all implemented POCUS in their daily practice during the educational program.

Conclusion This study emphasizes that a customized training program, considering the learning challenges faced by office-based GPs, can result in scanning proficiency that continues to develop in the months following the training.

Trial registration Clinical trials registration ID NCT05274581.

*Correspondence:
Camilla Aakjær Andersen
caakjaer@dcm.aau.dk
Full list of author information is available at the end of the article

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Background

Point-of-care ultrasound (POCUS) is increasingly used by general practitioners (GPs) working in primary healthcare [1]. Although evidence is sparse, studies suggest that selected POCUS use may reduce time-to-diagnosis [2] and health care costs [3].

To mine such benefits GPs must possess scanning competences [4]. Ultrasonography is a highly user-dependent examination and scanning competence necessitates the ability to integrate anatomy, image acquisition and interpretation with clinical knowledge [5]. A robust POCUS training program is therefore mandatory to ensure skills acquisition and minimize adverse effects resulting from misdiagnosis or mismanagement [6].

Systematic reviews have demonstrated that POCUS is a reliable tool for a trained generalist [7] and scanning competence is within reach following structured training [8], but training recommendations for office-based GPs are still missing [9]. GPs face practical educational challenges as they strive to obtain scanning competence, and training programs developed in secondary care are ill-suited to meet these challenges [10]. GPs typically work alone without easy access to more experienced colleagues. In contrast, hospital-based physicians can consult with their peers if they experience problems with interpreting ultrasound images.

Moreover, pathology is rarely encountered in an unselected primary care patient population, and developing routines in the recognition and interpretation of findings may be challenging. GPs manage a wide variety of clinical conditions and must be able to perform multiple scanning modalities, some of which may be infrequently used. This may lead to a decay in competency over time. An educational program tailored to meet the learning obstacles and educational needs of office-based GPs was developed based on the best available evidence and established learning principles [11].

The overarching aim of this study was to investigate whether this new educational program could lead to scanning competence (at the end of the program) and if scanning competence could be maintained over time (at a three-months follow-up). In addition, we evaluated the delivery of the educational program.

Methods

Study design

This study was conducted as the first in a series of studies following the medical research council's framework for implementing complex interventions [12]. Prior to a large-scale implementation, this hybrid effectiveness-implementation study [13] evaluated the effectiveness of a longitudinal educational program in a real-world setting while gathering information on its implementation.

Prior to the data collection, a study protocol was uploaded to clinicaltrials.gov (NCT05274581).

The study's reporting follows the STROBE guidelines [14].

Setting

The study involved GPs working in office-based general practice in Denmark. Denmark has a public healthcare system where patients are listed with specific GP clinics, which act as gatekeepers for other primary care healthcare providers and secondary care specialists [15].

GPs in Denmark have completed a medical education (6 years at university), resident training (1 year), and specialist training in general practice (5 years, including 2.5-year hospital rotations). During hospital rotations, trainees are introduced to ultrasound, but there is no formalized ultrasound training in the specialist training. Hence, formalized ultrasound training must be initiated by the GPs themselves. At the time of this study, around 12% of Danish GPs were using POCUS [16].

Continuous medical education for GPs is centrally organized under the wings of the Danish Medical Association for General Practitioners (Praktiserende Lægers Organisation PLO-e). The educational program in this study was included in PLO-e's course catalog for 2022. There were 20 available spots on the program and all GPs working in Danish general practice had the opportunity to sign up for the program between August 2021 and February 2022.

Participants

Participants were recruited through convenience sampling. The first twenty GPs who signed up for the program were included in the study if they worked in office-based general practice in Denmark, completed the educational program, and had access to an ultrasound device in their clinic during the study. GPs with possible conflicts of interest (e.g., industry affiliation related to the use of ultrasound) were excluded. We expected a participation rate of 80%, corresponding to 16 GPs and 160 completed OSAUS evaluations at the two timepoints.

The educational program

The educational program consisted of three teaching seminars over a period of three months, a curriculum of 10 POCUS applications (Additional file 1), and an online learning platform that provided educational support before, during, and after the teaching seminars[11]. The educational program included a total of 24 hours of on-site hands-on training, 2 hours of webinar lectures, and a minimum of 16 hours of guided self-study at home in the clinic).

The online platform included tailored educational material, a chat forum for participants, access to webinars, practical information, assignments, quizzes, and an overview of activities and grades. Specific *action cards* [17] for each of the 10 POCUS applications framed the examinations to the primary care setting. Activities, webinars, and assignments were made available for participants stepwise during the course, scaffolding the learning process. Initially, focus was on producing ultrasound images, then scanning healthy individuals, and, in the end, recognizing and interpreting pathology. While participating in the educational activities, GPs concurrently implemented ultrasound in their everyday clinical practice supported by mentors online according to their needs. Mentors were ultrasound training experts with experience in working in primary care. Throughout the course, mentors were tutoring four GPs by teaching at the seminars and supervising them remotely. The goal was to give attention to individual learning curves, build a solid foundation of ultrasound skills, and secure a sustainable implementation of POCUS in daily practice[11].

Data collection

The study was conducted between March 3rd and November 3rd, 2022. The following participant characteristics were collected at baseline: Age (years), gender (M, F, other), year of graduation from medical school, experience as a GP working in general practice (years), previous experience with ultrasound use (yes/no), prior training in ultrasound use (yes/no), scanner type (low range, mid-range, high end), type of employment (practice owner/employed/other), type of practice (collaboration, partnership, solo), location of practice (urban, rural, mixed), distance to nearest radiology department (km), number of patients assigned to the practice, and number of GPs working in practice.

To evaluate the delivery and implementation of the educational program, each participant's activity and completion of the educational elements (course day participation, webinar participation, completion of pre- and post-quizzes, and hand-in of assignments) was logged in the online platform. All participants were instructed to keep a logbook of all scans they performed from baseline to follow-up. In addition, participants were asked to report adverse events and near-miss cases associated with the use of POCUS during the study.

To evaluate the effectiveness of the educational program, participating GPs had their scanning competence assessed for each of the 10 POCUS applications included in the curriculum immediately after completing the training on the third teaching seminar (3 months after baseline) and again at follow-up (6 months after baseline). Scanning competence was assessed as 1) observed overall scanning competence on a scale from 7–35, 2) calculated scanning competence using a predefined cut-off, and 3) self-perceived scanning competence. Observed assessment of scanning competence was done by external POCUS experts, who were blinded to the participant's previous experience and learning process. Experts were randomly assigned to mentor with four participants, and each expert twice assessed the same four participants in all 10 POCUS exams.

Scanning competence was assessed using the generic Objective Structured Assessment of Ultrasound Skills (OSAUS) tool [18]. The OSAUS sum score consisted of seven items: 'indication for the examination', 'applied knowledge of ultrasound equipment', 'image optimization', 'systematic examination', 'interpretation of images', 'documentation of the examination', and 'medical decision-making'. Each item was rated using a five-point Likert-scale with descriptions of performance ranging from very poor (score $=1$) to excellent (score $=5$). All items were weighted equally, yielding a total score from 7 to 35 points for each POCUS application (Additional file 2). Previously, within obstetrics, a cut-off OSAUS score of 3.0 for trans abdominal fetal biometric scans and 2.5 for a systematic pelvic scan have been found to discriminate between novices and intermediate/expert users [19]. Hence, for this study, a mean score of three or more may be anticipated for users with some experience. Still, even consultants at a university department may score below three in some items.

Participants were also asked to assess themselves. In a paper questionnaire, they declared for each POCUS application if they felt they possessed sufficient POCUS scanning competence to perform the scan un-supervised in general practice (yes to a very high degree, yes to a high degree, yes to some degree, yes to a lesser degree, no, unsure). The expert assessors were blinded to this questionnaire.

Data management

All study data registered online was transferred and imputed into Microsoft Excel (Microsoft 365, Microsoft Corporation, 2021). Owing to a poor WIFI connection, assessment data was collected using paper sheets. Two research assistants independently imputed, cleaned, and prepared the collected data for analysis. CAA was involved in resolving inconsistencies between these two data sets. All data were stored on a secure server at Aalborg University, Denmark, and handled according to the General Data Protection Regulation.

Statistics

All analyses were performed by a statistician blinded to participants' identities according to a predefined statistical analysis plan (Clinical trials NCT05274581). A predictive mean matching (mm) imputation method was applied to account for missing values in the OSAUS item scores.

The analysis of OSAUS sum scores and item scores was performed using linear regression or repeated measures ANOVA, with participants being the random effect. Cohen's d was calculated to estimate effect size. To account for interrater variation, we calculated an average score for each expert and adjusted results so that experts had the same average score. Sensitivity analyses were performed and the results of both complete case and adjusted analyses are reported. Distributions of baseline values are presented as mean (SD) and median [IQR] for continuous or n (%) for categorical variables. Fishers exact test was used to compare out sample to the general population of GPs in Denmark. OSAUS scores are presented in tables as summarized complete case (raw data) and statistical optimal data (including imputation and adjustment for expert variation). Results with p-values < 0.05 are considered statistically significant. All statistical analyses were performed using STATA version 17 (StataCorp, Texas, USA).

Results

Two GPs dropped out due to illness prior to completing the educational program, resulting in 18 GPs participating in the study. Background characteristics are provided in Table 1 and comparison to the general population of GPs in Denmark is provided in Additional file 3.

Implementation related outcomes

Figure 1 describes the variation in the participants' commitment and participation in the educational elements of the program. The number of POCUS examinations performed during the program varied from 14 to 98, with a mean of 44.2 (SD 22.9) scans per GP. This variation in use continued in the three months after the program, from 0 to 59, with a mean of 25.6 (SD 16.0) scans per GP (Additional file 4). No adverse events or near-miss cases were reported during the study.

Effectiveness-related outcomes

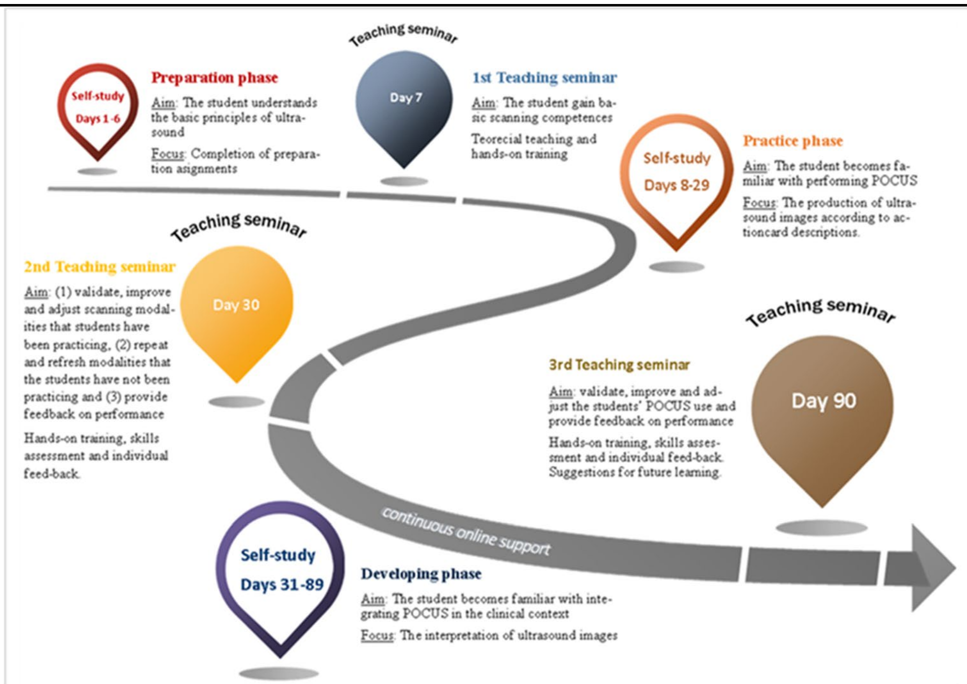
After completing the educational program, participants' OSAUS sum scores ranged from 24.1 to 28.9, corresponding to 68.9% to 82.3% of the maximum score depending on the POCUS application (Overall mean score across modalities: 27.0 (SD 1.8)). At follow-up, the scores had increased for all POCUS applications, ranging

Table 1 Background characteristics of participants

Participant characteristics (*N*=18)			**Type of practice**		
Age (year)	49 [45–53]	48.8 (6.3)	Solo practice without collaboration		1 (5.6%)
Gender (Female)		10 (55.6%)	Solo practice in collaboration		3 (16.7%)
			Partnership practice		14 (77.8%)
Experience of participants			**Location of practice**		
Experience as a medical doctor (years)	21 [17–23]	20.7 (5.9)	rural		7 (38.9%)
Experience as a general practitioner (years)	9.5 [7–15]	10.8 (6.0)	city		1 (5.6%)
Experience with POCUS (years)	0 [0–1.5]	0.9 (1.6)	mixed		10 (55.6%)
Previous POCUS training		15 (83.3%)*			
			Distance to nearest radiology department (km)		
Region			9 [1–15]		12.0 (11.4)
North Denmark Region		0 (0%)			
Central Denmark Region		7 (38.9%)	**Size of the clinic**		
Region of Southern Denmark		7 (38.9%)	GPs working in the clinic	3 [2–8]	4.3 (3.2)
Region Zealand		3 (16.7%)	Patients listed with the clinic	6,000 [4,100-12,000]	7,263.9 (4,507.7)
Capital Region of Denmark		1 (5.6%)			

There were no missing data regarding background characteristics

* Seven participants had attended an ultrasound workshop years ago, six participants had received some informal training during residency, and two participants had previously been trained in a different medical specialty



Educational phase	Educational activity	Online activity	Feedback on performance	Participation N (%)
Preparation phase	Webinar 1(Introduction)			16 (89)
	Theoretical self-study (First 5 scans)			17(94)
		Motivational description		13 (72)
		Pre-quiz 1		17(94)
Teaching seminar 1	Hands-on training (First 5 scans)			18(100)
Practice phase		Post-quiz 1		16(89)
	Webinar 2 (Documentation)			15(83)
	Performance of minimum 15 scans*			10 (56)
			Upload of scans to mentor**	15(83)
	Theoretical self-study (Next 5 scans)			-
		Pre-quiz 2		18(100)
Teaching seminar 2	Hands-on training (Next 5 scans)		Assessment (First 5 scans)	17(94)
Developing phase		Post-quiz 2		16(89)
	Webinar 3 (pathology)			12(67)
	Webinar 4 (cases)			12(67)
	Performance of minimum 30 scans*			5 (28)
			Upload of scans to mentor**	14(77)
	Theoretical self-study (Pathologies)			-
		Pre-quiz 3		17(94)
Teaching seminar 3	Hands-on training (All ten scans)		Assessment (All ten scans)	18(100)
		Post-quiz 3		10(56)

* Participants registered between 0-32 (mean 14) scans in the practice phase and 11-72 (mean 30) scans in the developing phase.
** In the practice phase, three participants uploaded no scans for review, 15 participants uploaded five scans, and in the developing phase, four participants uploaded no scans, three uploaded one scan, one participant uploaded four scans, and ten uploaded five scans.

Figure 1 Point-of-care ultrasonography educational program for general practitioners from 28.3 to 32.4, corresponding to 80.9% to 92.6% of the maximum score (Overall mean score across modalities: 30.6 (SD 2.0)). The increase in OSAUS score was statistically significant for all POCUS applications (Table 2). Variation was found for the seven items'scores, with the lowest scores being related to the technical performance of POCUS examinations (Applied knowledge, Image optimization, and Systematic examination). Still, significant improvements were found for all items at follow-up (Table 3). Cohen's d estimates represented a medium or large effect size on both OSAUS sum scores and item scores. Additional files 5 and 6 provide an overview of the effects of the imputation and expert adjustments on the OSAUS sum and item scores.

The proportion of participants with formal scanning proficiency (OSAUS item score >2 on all items for a given POCUS application) varied from 10 (scanning abdomen for ascites/bleeding) to 18 (knee effusion) out of the 18 participants. At follow-up, the proportion of participants with formal scanning proficiency increased for hydronephrosis, residual urine, gall stones, childhood constipation, ascites, and abscess/cellulitis. The proportion of formally proficient POCUS users remained unchanged for pregnancy, location of intrauterine device, and knee effusion but decreased for pleural effusion (Table 4).

Evaluating graphically, we found a relationship between the average OSAUS sum score after the educational program and GPs' age as well as prior POCUS experience, suggesting that younger GPs and GPs with prerequisites obtained higher scores. In contrast, less clear tendencies were found for course participation, number of completed quizzes and assignments, and number of performed scans (Additional file 7). Likewise, at follow-up, we found a tendency suggesting that having a high score at the end of the educational program also resulted in a high score at follow-up. In contrast, no clear relationship was found between OSAUS sum score at follow-up and the number of performed examinations.

At follow-up, the proportion of participants who rated themselves as being able to perform a specific POCUS application unsupervised in general practice (to a very high degree or to a high degree) increased for all applications (Figure 2).

Table 2 Participants' OSAUS score at the end of the ultrasound course and at follow-up

Assessment of the performance of different ultrasound examinations

	Summarized OSAUS score* after the course			**Summarized OSAUS score* at follow-up**			**Difference in mean**		**Standardized effect size**
	Min/max	**Mean (SD)**	**Median [IQR]**	**Min/max**	**Mean (SD)**	**Median [IQR]**	**Diff (95%CI)**	**p-value**	**Cohen's d**
Kidney (Hydronephrosis)	19/34	26.6 (4.3) **26.9 (3.0)**	26.0 [24–29] **26.6**	19/35	30.6 (4.2) **30.7 (4.1)**	31.5 [28–34] **31.0**	4.0 (1.7–6.2) **3.8 (1.4–6.1)**	0.001 **0.001**	0,94 **1,06**
Urinary bladder (Residual urine)	20/34	26.5 (3.8) **26.6 (2.9)**	26.0 [25–29] **26.0**	21/35	31.4 (3.7) **30.9 (3.5)**	32.0 [30–34] **31.1**	4.4 (3.0–5.8) **4.3 (2.9–5.7)**	<0.001 **<0.001**	1,17 **1,34**
Gall bladder (Stone/cholecystitis)	21/34	27.7 (4.6) **27.7 (2.7)**	27.5 [24–32] **27.3**	22/35	30.5 (3.8) **30.3 (3.7)**	31.0 [29–33] **30.0**	2.6 (0.6–4.7) **2.7 (0.6–4.8)**	0.010 **0.012**	0,62 **0,83**
Rectum (Child constipation)	17/34	27.6 (4.8) **27.6 (3.5)**	27.5 [25–31] **27.6**	21/35	31.1 (4.1) **30.7 (2.9)**	32.0 [31–34] **30.6**	3.4 (1.0–5.8) **3.1 (1.0–5.3)**	0.005 **0.003**	0,76 **0,96**
Abdomen (Ascites/bleeding)	14–32	24.1 (4.4) **24.1 (3.6)**	22.5 [22–27] **24.3**	21/35	29.5 (3.9) **29.5 (2.6)**	30.0 [27–33] **29.5**	5.4 (3.9–6.9) **5.4 (3.9–6.9)**	<0.001 **<0.001**	1,30 **1,72**
Lungs (Pleural effusion)	16/34	25.9 (5.1) **25.9 (3.2)**	26.0 [22.29] **26.0**	14/35	28.3 (6.4) **28.2 (5.6)**	31 [25–33] **28.3**	2.6 (0.3–4.8) **2.3 (−0.2-4.7)**	0.022 **0.075**	0,45 **0,50**
Uterus (Pregnancy)	20/35	28.9 (4.3) **28.4 (2.4)**	30.0 [27–32] **28.4**	20/35	30.6 (4.9) **30.7 (3.2)**	33.5 [27.5–34] **32.0**	2.2 (0.3–4.0) **2.3 (0.5–4.1)**	0.020 **0.010**	0,48 **0,81**
Uterus (Intrauterine device)	21/35	28.2 (3.9) **28.3 (3.1)**	29.0 [25–30] **28.2**	22/35	31.6 (3.7) **31.5 (2.8)**	32.0 [31–34] **31.1**	3.2 (1.6–4.9) **3.3 (1.7–4.8)**	<0.001 **<0.001**	0,84 **1,12**
Knee (Knee effusion)	19/35	28.1 (5.3) **28.0 (3.2)**	28.5 [25–33] **27.6**	21/35	31.1 (4.8) **31.0 (2.2)**	32.5 [31–35] **31.0**	3.0 (1.5–4.5) **3.0 (1.5–4.5)**	<0.001 **<0.001**	0,59 **1,09**
Skin (Abscess/cellulitis)	15/35	27.1 (5.1) **27.0 (4.4)**	27 [25–31] **26.3**	22/35	32.4 (3.4) **32.7 (4.8)**	33.0 [32–35] **32.0**	5.3 (2.7–7.9) **5.7 (3.1–8-3)**	<0.001 **<0.001**	1,22 **1,24**

The 18 participating GPs had their ultrasound competencies evaluated in 10 ultrasound examinations (N=180) twice. Evaluation was made using the Objective Structured Assessment of Ultrasound Skills (OSAUS) scale for point-of-care ultrasonography performance resulting in seven item score (each rated from 1 to 5) and a summarized OSAUS sum score (7–35) for each ultrasound application. Missing items owing to failed registration after the course:12/1260 and at follow-up: 16/1260

* Summarized OSAUS scores are shown for complete case (normal text) as well as imputed and mentor-adjusted data (**bold text**)

Table 3 OSAUS item scores at the end of the ultrasound course and at follow-up

Assessment of the different elements of performing an ultrasound examination

	Summarized item scores* after the course			Summarized item scores* at follow-up			Difference in mean		Standardized effect size
	Min/max	Mean (SD)	Median [IQR]	Min/max	Mean (SD)	Median [IQR]	Diff (95%CI)	p-value	Cohen's d
Indication	30/50	44.9 (5.6) **44.1 (2.7)**	47.0 [45–48] **44.0**	36/50	46.9 (4.1) **47.1 (2.9)**	49.0 [45–50] **46.6**	2.4 (1.1–3.7) **3.0 (1.4–4.6)**	<0.001 **<0.001**	0,49 **1,07**
Applied knowledge	27/50	38.0 (6.1) **38.2 (4.2)**	37.0 [34–43] **37.9**	31/50	44.8 (5.6) **45.1 (4.7)**	45.5 [41–50] **44.8**	6.3 (4.2–8.4) **7.0 (5.2–8.7)**	<0.001 **<0.001**	1,08 **1,57**
Image optimization	28/47	34.4 (5.1) **34.6 (4.0)**	34.0 [31–37] **34.7**	28/50	40.5 (5.7) **39.4 (4.8)**	38.0 [37–45] **39.3**	6.3 (4.4–8.2) **4.8 (2.7–7.0)**	<0.001 **<0.001**	1,16 **1,09**
Systematic examination	26/46	36.4 (5.8) **35.9 (4.0)**	36.0 [32–40] **35.9**	27/50	41.4 (5.9) **41.3 (3.9)**	41.0 [40–46] **41.3**	5.1 (3.7–6.5) **5.4 (3.7–7.1)**	<0.001 **<0.001**	0,87 **1,37**
Interpretation of images	29/46	38.8 (5.8) **38.1 (4.0)**	39.5 [34–44] **37.5**	31/49	43.7 (5.9) **43.6 (2.5)**	46.0 [44–48] **43.7**	5.0 (2.7–7.3) **5.5 (3.4–7.6)**	<0.001 **<0.001**	0,85 **1,65**
Documentation	27/48	38.9 (6.6) **38.5 (4.6)**	38.5 [34–46] **37.5**	28/50	43.9 (5.7) **43.7 (3.8)**	46.0 [42–48] **44.7**	4.9 (2.8–7.0) **5.2 (3.1–7.2)**	<0.001 **<0.001**	0,79 **1,23**
Medical decision-making	29/48	41.8 (6.0) **41.0 (3.3)**	44.0 [39–46] **42.7**	30/50	46.3 (5.4) **46.0 (3.2)**	49.0 [46–49] **46.5**	4.4 (2.6–6.2) **5.1 (3.0–7.2)**	<0.001 **<0.001**	0,77 **1,57**

The 18 participating GPs had their ultrasound competencies evaluated in 10 ultrasound examinations (N=180). Evaluation was made using the Objective Structured Assessment of Ultrasound Skills (OSAUS) scale for point-of-care ultrasonography performance resulting in seven item scores (each rated from 1 to 5) for each ultrasound application. Missing items owing to failed registration after the course:12/1260 and at follow-up: 16/1260

* Summarized item scores across scanning modalities are shown for complete case (normal text) as well as imputed and mentor-adjusted data (**bold text**). For each OSAUS item the sum of the scores from the ten applications can vary between 10 (minimum) and 50 (maximum)

Discussion

One concern about using POCUS in primary care is whether GPs can maintain proficiency in scanning if they only use the ultrasound device a few times a day or less[4]. Our study reflected the infrequent use described in previous cohort studies [20–24] and demonstrated that for selected applications, it is possible to obtain proficiency and retain this in the months following training. A recent study describing a 10-week tailored training program for primary care doctors also found proficiency at the end of program [25], highlighting the need for longitudinal training to reach sustainable results. Whether similar results can be found for GPs, who have trained in less comprehensive educational programs is still being determined. However, in a previous study in which OSAUS evaluated GPs with more than six months of POCUS experience and variable POCUS training[8] there was a more significant individual variation across POCUS applications as well as more considerable variations between participants compared to the results of this study. The educational program described in this study varies from previously described training programs for GPs[9] in its focus on implementations and individualization[11]. During the program focus was on individual strengths and weaknesses in terms of scanning. The GPs' self-assessment of competence was included as secondary outcomes despite being prone to subjective bias. This was done to evaluate whether insight into own abilities was obtained, and we found that self-assessment of scanning competence (Figure 2), aligned nicely with the assessment done by the experts. In the third and final teaching seminar, attention was given to participants' learning process after the educational program. This might explain the increase in scanning competence found three months after the program – even in modalities that where rarely used. Hence, including individual feedback on performance may create self-awareness, potential for further development, and possibly safer use of the technology. It is, however, possible that awareness of the forthcoming second competence assessment retained and motivated GPs to continue to scan and practice in the months following the program: Longer follow-up is needed to determine if GPs continue to use POCUS in their daily practice and whether scanning proficiency can be maintained over time.

Traditionally, a fixed number of performed ultrasound examinations have been the certification goal [26]. Recently there has been a shift towards recommending individual competence assessment instead [27] as simply requiring an arbitrary number of examinations has been found insufficient [28]. Our findings support this, as we found no association between the number of performed examinations and scanning competence. Still, the missing relationship between educational elements, including number of scans and OSAUS sum scores, should be

Table 4 Scanning proficiency at the ultrasound course's end and follow-up

Assessment of scanning proficiency					
Scanning modality	**After the course**		**At follow-up**		**Diff** (%)**
	N	**Proportion of participants with formal scanning proficiency*** ***N (%)***	**N**	**Proportion of participants with formal scanning proficiency*** ***N (%)***	
Kidney (Hydronephrosis)	17 **18**	12 (70.6) **15 (83.3)**	18 **18**	17 (94.4) **18 (100.0)**	23.8 **16.7**
Urinary bladder (Residual urine)	17 **18**	11 (64.7) **15 (82.9)**	17 **18**	16 (94.1) **18 (100.0)**	28.1 **17.1**
Gall bladder (Stone/cholecystitis)	18 **18**	13 (72.2) **16 (88.9)**	17 **18**	14 (82.4) **17 (94.4)**	10.7 **5.5**
Rectum (Child constipation)	18 **18**	13 (72.2) **15 (83.3)**	17 **18**	16 (94.1) **17.9 (99.6)**	22.4 **16.2**
Abdomen (Ascites/bleeding)	18 **18**	9 (50.0) **10 (55.6)**	18 **18**	13 (72.2) **17 (94.4)**	22.2 **38.9**
Lungs (Pleural effusion)	17 **18**	12 (70.6) **15 (83.3)**	18 **18**	12 (66.7) **12 (66.7)**	−1.1 **−16.6**
Uterus (Pregnancy)	17 **18**	15 (88.2) **17 (93.8)**	16 **18**	16 (81.3) **16.8 (93.6)**	−4.1 **−0.2**
Uterus (Intrauterine device)	18 **18**	17 (94.4) **17 (94.4)**	16 **18**	15 (93.8) **17.0 (94.2)**	−0.7 **-0.2**
Knee (Knee effusion)	18 **18**	16 (88.9) **18 (100.0)**	18 **18**	16 (88.9) **18 (100.0)**	0 **0**
Skin (Abscess/cellulitis)	15 **18**	12 (80.0) **17 (93.3)**	18 **18**	17 (94.4) **17 (94.4)**	14.4 **1.1**
All modalities					

Results are shown for complete case (normal text) as well as imputed and mentor-adjusted data (**bold text**)

* External reviewers rated the following OSAUS items: Indication, applied knowledge, Image optimization, Systematic examination, Interpretation of images, Documentation, Medical decision-making on a scale from 1–5. Reviewer-rated formal scanning proficiency includes participants who obtained an item score >2 on all items

** Difference in proportion of participants with scanning score > 2 on all items calculated using a repeated measures model

interpreted with caution owing to the lack of statistical power and interaction between elements.

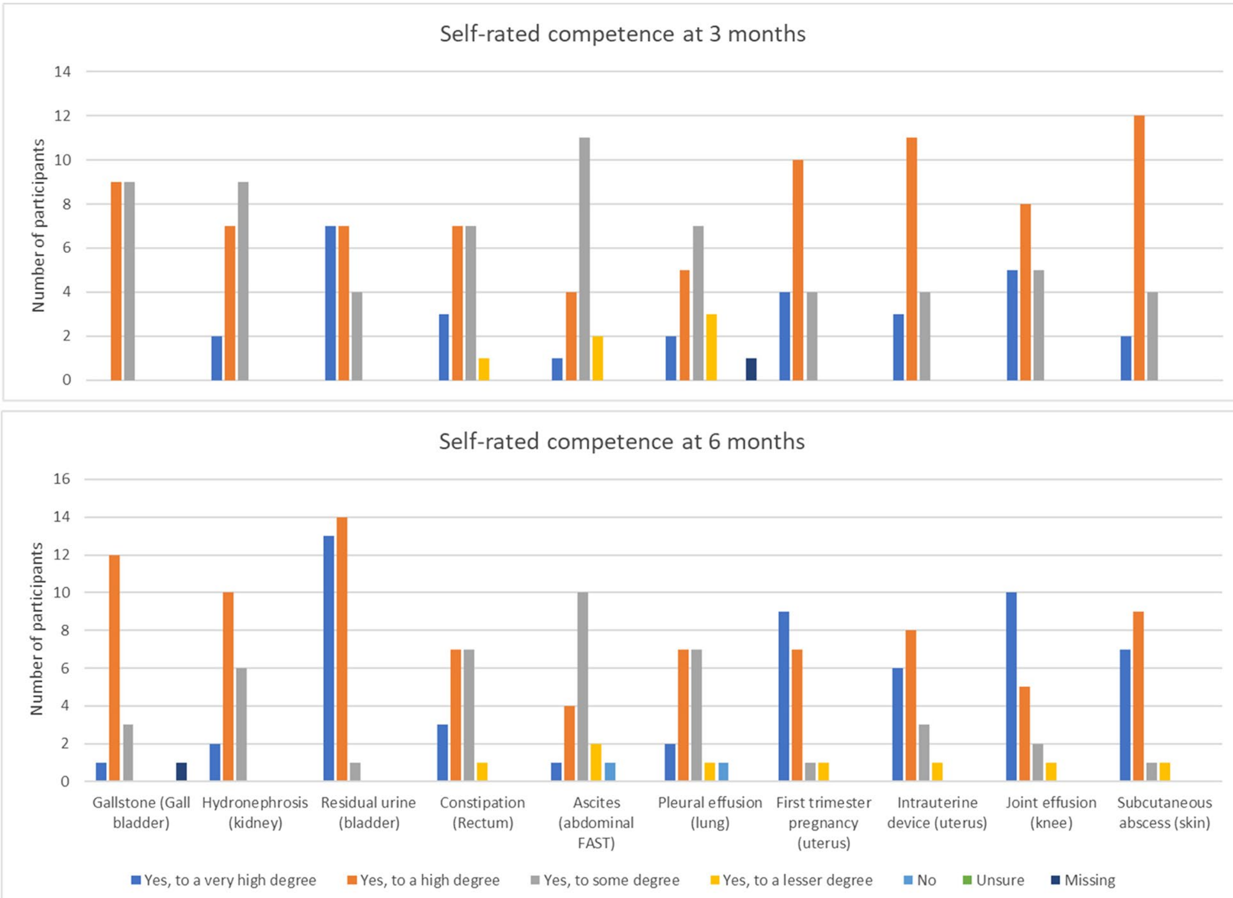
Various assessment tools have been used to evaluate scanning competence following POCUS training[9]. The detailed evaluation of multiple aspects of performing POCUS made in this study offers insight into what is most challenging to learn and master for novices and where efforts should be made in terms of equipping the participants with self-directed learning in the months following an educational program.

Previous studies have found that diagnostic accuracies vary across POCUS applications[7 9] and in our study, POCUS applications such as lungs (pleural effusion) and abdomen (ascites/bleeding) caused more difficulties for participants in the evaluations. This may be explained by the fact that some applications are easier to learn to master than others or that some applications were also rarely used (Additional file 4). This confirms previous findings [29], which emphasize the need for a curriculum of POCUS applications that are simple, easy to learn, and frequently encountered.

Implications for future research and practice

More and more research support the use of POCUS by frontline physicians as an aid in the diagnostic process[21] [30, 31]. Recently, the European organization of World Family Doctors (WONCA Europe) issued a position paper advocating for the integration of POCUS in general practice [32] and articles have drawn out the perspectives of POCUS use in primary care in countries like the UK, where POCUS in not standard care [33, 34]. The obstacles to implementing POCUS include lack of opportunity (time and equipment), capability (lack of training opportunities), and motivation (financially and culturally) [35]. However, POCUS use increases even in healthcare systems without financial incentives for using it, and the expenses related to its introduction have to be covered by the GPs themselves. Position papers from GP organizations will inevitably push this development further. Guidelines and recommendations for use still need to be more extensive and largely experience-based or adapted from a secondary care setting. Hence, policymakers and stakeholders within the GP community must attend to this to secure the appropriate use of the technology. This study offers some insights with training, but more research is needed in terms of patient prognosis following different POCUS applications and effects on health care costs.

The educational program described in our study is resource demanding. There is a need to develop quick and easy-to-use solutions for sharing ultrasound videos and receiving feedback during training without compromising data-sharing regulations. Artificial intelligence (AI) may offer new solutions for this. More research is also needed to explore methods to support office-based GPs' use of POCUS over time and to develop next-level ultrasound courses for the experienced GPs. Besides testing feed-back solutions, future research should explore other quality-assurance measures and identify possible pitfalls in order to promote safe use of the technology.



The participants rated themselves by answering the question: Are you able to perform this POCUS scan unsupervised in general practice? (Yes, to a very high degree, yes to a high degree, yes to some degree, yes to a lesser degree, no, unsure).

Figure 2 The participants' self-rated level of scanning proficiency

Limitations

This small hybrid effectiveness-implementation study was designed to concurrently test the feasibility of delivering an educational program and evaluate learning outcomes – giving way for adaptions to be made before moving on to a large-scale implementation of the program. This design required that the data collection did not interfere with the delivery of the program. Different study designs could e.g. have incorporated an OSAUS assessment by multiple reviewers that included interrater reliability measures, diagnostic accuracy estimation of GP-performed scans compared to a gold standard or enabled an in-depth understanding of individual learning curves.

The study contained a detailed evaluation of scanning competence with only 15(1.2%) missing values after the education program and 16(1.3%) at follow-up. Half of the missing participants originated from two participants who missed out on the assessment of one POCUS application (due to a scheduling issue). The other half were scattered randomly among participants, modalities, competences, and time points. Hence, selection bias due to missing values is very unlikely. Nevertheless, complete case and analyses after multiple imputation and expert adjustments were performed and compared with agreeable results (additional files 5 and 6).

Predictive mean matching was used for imputation. Compared to other imputation methods, it usually imputes less implausible values and takes heteroscedastic data into account more appropriately. Unfortunately, combining this imputation technique with the bootstrap calculation of SE, CI, and p-values is somewhat intractable, and we had to rely on the number of sub-score observations to produce sufficiently normally distributed means and differences and hereby valid estimates of CI.

The low number of participating GPs in this study compromises the generalizability of our results, and larger cohorts in more representative samples are needed to validate the results. Our participants were younger than the general population and might be a selected group with a particular interest in POCUS. Still, all were close-to ultrasound novices prior to the study, and large variations were found in background characteristics as well as frequency of use. However, we only assessed a proportion of the scans that might be of relevance for general practice, and the follow-up was not long, considering that POCUS might be used throughout a professional career. Using a three-month follow-up was feasible when restricting GPs in attending other POCUS related courses, however, we acknowledge that a longer follow-up period could be more suitable when measuring retention.

A limitation in this educational program is possible variation in the quality of training delivered by different mentors. Prior to the program, all mentors completed a train-the trainer module but individual variation cannot be excluded. For the evaluation, each expert assessor rated participants who had been taught by the same mentor, with the results adjusted to account for variation.

Conclusion

This study demonstrated that office-based GPs can obtain scanning competence in selected POCUS applications after participating in a tailored training program that meets their educational challenges. Using external reviewers and a generic assessment tool, we found high levels of formal scanning competence across the 10 POCUS applications although some applications caused more difficulties than others. Furthermore, the study demonstrates how the scanning competences were maintained and increased in the months following training despite a low frequency of performed scans. While the increase in scores was statistically significant, it is important to note that this finding is based on a small sample size, and additional research with larger cohorts and longer follow-up is needed to validate these results.

Abbreviations

POCUS	Point-of-care ultrasonography
GPs	General Practitioners
PLO-e	Danish Medical Association for General Practitioners (Praktiserende Lægers Organisation) continuous medical education provider
FAST	Focused Assessment with Sonography in Trauma
OSAUS	Objective structured assessment of ultrasounds skills

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-07356-8.

Additional file 1.

Additional file 2.

Additional file 3.

Additional file 4.

Additional file 5.

Additional file 6.

Additional file 7.

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Authors' contributions

All authors made valuable scientific contributions to the manuscript. CAA and MBJ designed the study and wrote the draft of the protocol. CAA was responsible for the data collection. AR wrote the draft for the statistical analysis plan. SLC made statistical analysis. UM, TL, TMJ, LD, NS, and BS were teachers in the training program. OG, MBJ, LP, CS, SKA performed the OSAUS evaluations of scanning competence.

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Data availability

Anonymized data are available upon reasonable request by the authors.

Declarations

Ethics approval and consent to participate

The study was performed in accordance with the Declaration of Helsinki. The project was notified to the regional ethical committee (Den Videnskabsetiske Komité for Region Nordjylland, reference number 2022-000764), which responded that, according to Danish Law (komitélovens § 14, stk. 2), no ethical approval was needed for this project.
The project was also registered and conducted according to the regulations of the Danish Data Protection Agency (registration number ID-242-2).
All participating GPs gave their informed consent to participate.

Consent for publication

There are no details, images or videos that would allow conclusions to be drawn about a person.

Competing interests

The authors declare no competing interests.

Author details

[1]Center for General Practice at Aalborg University, Aalborg University, Selma Lagerløfs Vej 249, Aalborg, Gistrup DK-9260, Denmark. [2]Research Data and Biostatistics, Department of Clinical Medicine, Aalborg University, Aalborg, Denmark. [3]Department of Physiotherapy, University College Northern Denmark, Aalborg, Denmark. [4]Department of Radiology, Aarhus University Hospital, Aarhus, Denmark.

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