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Ultrasound education, competencies and expected future use among medical interns in Denmark: a national cross-sectional study

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Abstract

Background Point-of-care ultrasound is increasingly used across medical specialties, calling for timely and relevant ultrasound education in specialty training. To enable customizing such education, we aimed to explore medical interns' received ultrasound education during medical school and internship, perceived scanning competencies, evaluation of received education, future expectations for using ultrasound, and tendencies for perceiving ultrasound competence.

Methods This was a national cross-sectional study. We developed a questionnaire based on a theoretical conceptual model, individual interviews with medical interns and focus groups with medical students, followed by pilot testing. The questionnaire was distributed to all medical interns in Denmark ($N=1231$). Data were summarized with descriptive statistics. Differences between universities and tendencies for perceiving ultrasound competence were analyzed with Fisher's exact tests and modified Poisson regression, respectively.

Results Responses from 420 (34.1%) interns were included. Although varying across medical schools, 95.7% received formal ultrasound training and 86.0% encountered ultrasound examinations through clinical rotation. During internship, 44.2% received formal training, while 68.5% had to pursue it independently. Ultrasound examinations during clinical work were observed by 73.2% and performed by 47.6%. Common ultrasound usage barriers were insufficient scanning routine, supervision, knowledge, confidence and mental surplus. Ultrasound competence gain from medical school and internship was reported by 75.2% and 55.3%, respectively, but mainly to lesser/some extent. Most desired more training, expected to use ultrasound in the future (71.0%) and considered it a core competence (73.0%). Perceived ultrasound competence was significantly associated with receiving practical (RR: 4.08) or both practical and theoretical education (RR: 4.34) in medical school, and practical training on patients (RR: 1.09), required number of performed scans (RR: 1.06), competence test(s) (RR: 1.07), and/or consulting books/encyclopedia (RR:1.07) during internship.

Conclusions Ultrasound training is part of medical school curricula but varies in type and extent. While most encounter and many use ultrasound during internships, formal training is less integrated. Most desire more training and attitudes towards future ultrasound usage are positive. Filled curricula pose dilemmas for prioritization and several barriers prevail for using ultrasound, representing missed opportunities for competence development and maintenance. Training governance and scaffolding continuous learning may be needed.

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Trial registration None.

Keywords Ultrasonography, Point-of-care ultrasound, Ultrasound education, Medical education, Medical internship, Scanning competence, Survey

Background

Ultrasound in medicine is typically done as a standard comprehensive examination performed by imaging specialists or as point-of-care-ultrasound (POCUS) performed bedside by clinicians [1]. Increasing POCUS utilization across specialties, coupled with affordability of handheld equipment and user-dependency of the technology, suggests that future medical practitioners need a fundamental understanding of POCUS application [2, 3]. Unskilled operators may misinterpret findings, possibly leading to mistreatment, patient anxiety, further examination needs, and delayed correct treatment [4, 5]. Ultrasound education is thus paramount to ensure necessary competencies and avoid misdiagnosis.

Internationally, universities consequently work on integrating POCUS curricula into medical education [6–11]. Curricular ultrasound can increase medical students' technical knowledge, fundamental understanding, and self-assurance for using ultrasound [12, 13], and even minimal training can provide them the competencies necessary to supplement physical examinations with POCUS [14]. Moreover, using ultrasound may enhance medical students' understanding of anatomy and pathology [11, 15]. However, there is a large variation in the extent and type of ultrasound training across countries and universities [16]. The amount and quality of students' ultrasound training depend on available equipment, educational approach, and faculty skill set [8, 17, 18]. In addition, previous recommendations for undergraduate ultrasound training have been based on consensus statements rather than evidence and the optimal format and way of curriculum implementation is not known [19].

Within some specialties, e.g., cardiology and gynecology, scanning competence is already a fundamental skill acquired during residency [20]. In other specialties, including family medicine, internal medicine, and pediatrics, POCUS-use is evolving, and efforts are made to integrate and scaffold ultrasound training in residency programs [21–24]. Competency acquisition in simple scans is found possible through short courses, while other more advanced examinations require continuous education, numerous clinical examinations, and frequent supervision [25, 26]. Consequently, POCUS experience and competence vary across specialties, and the level of postgraduate ultrasound education largely depends on medical specialty and individual preferences.

The World Federation for Ultrasound in Medicine and Biology (WFUMB) recommends that ultrasound education for medical students [13] and other trainees [1] should include both theoretical and practical components: theoretical instruction should cover physics, knobology, image optimization, examination techniques, anatomy, physiology, and pathologies, while practical training is essential to develop visuospatial and visuomotor skills necessary for managing transducers and acquiring ultrasound images. However, it is unknown whether these recommendations are followed in education of future medical practitioners/specialists and how the offered training is perceived by the young doctors.

To enable customizing ultrasound education in medical school and residency programs and thereby timely provide future medical specialists the relevant competencies, knowledge is needed on the foundation of ultrasound training and experiences received prior to enrollment in specialty training.

Therefore, we aimed to explore which ultrasound education medical interns in Denmark had received during medical school and internship. In addition, we aimed to explore their perceived scanning competencies, their evaluation of their received ultrasound education, and their future expectations regarding using ultrasound. Finally, we aimed to explore tendencies for perceiving ultrasound competence.

Methods

This study was reported in accordance with the STROBE checklist for cross-sectional studies.

Study design

National cross-sectional survey.

Setting and participants

The participants were medical doctors in their internship year. In Denmark, medical education is taught at Aalborg University (AAU), Aarhus University (AU), University of Copenhagen (CPH), and University of Southern Denmark (SDU). Medical school takes six years, after which graduates are allowed to practice medicine under supervision. To achieve authorization for unrestricted practice and initiate residency training, a one-year internship with supervised basic clinical training must be passed [27]. The internship corresponds to foundational program, medical officer, house officer training period, or

housemanship [28]. It includes two six-month employments: one in secondary care followed by one in primary care. Upon 5–6 years residency training, specialist certification can be granted [27]. At the time of this study, ultrasound training was only mentioned in the official curriculum of one medical school in Denmark (SDU) [29, 30] even though a previous study suggests that ultrasound is integrated at CPH too [16]. Likewise, ultrasound training is not part of the official training program for interns, but some departments offer short courses.

Recruitment

The secretariate for postgraduate medical training in Denmark sent an e-mail invitation to all interns on December 19th, 2022 ($N=1231$). The e-mail contained study description, survey link, and declaration of consent for participation. Interns who attended medical school in Denmark were eligible for participation. The e-mail contained an opportunity to win cinema tickets to enhance recruitment. Reminders were sent after two weeks. Additionally, the survey was posted in two Facebook groups for interns on January 23rd and February 6th, 2023. The survey closed March 1st, 2023.

Questionnaire development

The questionnaire (Additional file 1) was developed and validated as described in Fig. 1, using previously published studies [4, 31, 32].

Outcome measures

Participants were asked to provide the following background information: age, gender (female, male, other), year of medical school graduation, university attended (AAU, AU, CPH, SDU, other), and internship employments.

Ultrasound education in medical school

The participants were asked to specify any encountered formal ultrasound education, its timing (bachelor, master, both), ultrasound encounters during clinical rotation, and tests of ultrasound competency.

Ultrasound education in internships

Participants were asked to specify any encountered formal ultrasound education during internship; included educational components; ultrasound encounters in clinical work; and any encountered barriers for learning (scanning opportunities, supervision access and frequency, barriers for scanning, independent search for ultrasound education/training).

Selected ultrasound applications

Ultrasound competencies were investigated as (1) received education in and (2) self-assessed ability to scan specific anatomical structures.

Evaluation of ultrasound education

Ultrasound education was evaluated as degree of self-assessed scanning competencies obtained during (1) medical school and (2) internship; desires for more ultrasound education in (3) medical school and (4) internship; and overall (5) sufficiency of ultrasound education and (6) efforts expected to improve competencies.

Expectations of future ultrasound use

Questions were asked regarding expectations of future specialization; expectation for using ultrasound in future work; perceptions of ultrasound as a core competence for interns; and beliefs of ultrasound as helping to recruit residents into primary care. The latter was investigated due to current national and international challenges regarding recruitment of primary care [33].

Tendencies for perceiving ultrasound competence

Perceived ultrasound competence acquisition was investigated for correlations with types of ultrasound education (theoretical, practical, both) and ultrasound tests in medical school; and as received educational components in ultrasound and number hereof during internship.

Data management and analysis

Data was collected anonymously with SurveyXact (Rambøll, Aarhus, Denmark) and stored on a secure server at AAU. STATA V.15.0 (StataCorp, College Station, Texas, USA) was used for analysis. Continuous variables were summarized as median and IQR and categorical variables as proportions. Free-text responses were reviewed, described and, if possible, re-classified into existing categories. Registration of incorrect age, self-contradictory, multiple, or empty responses were identified as invalid responses. Correction or exclusion hereof was discussed and documented.

Differences between universities regarding ultrasound education and competencies obtained from medical school were tested using the Fisher's Exact test. To enable direct estimation of relative risk, modified Poisson regression models [34] were used to test associations between formal ultrasound education received

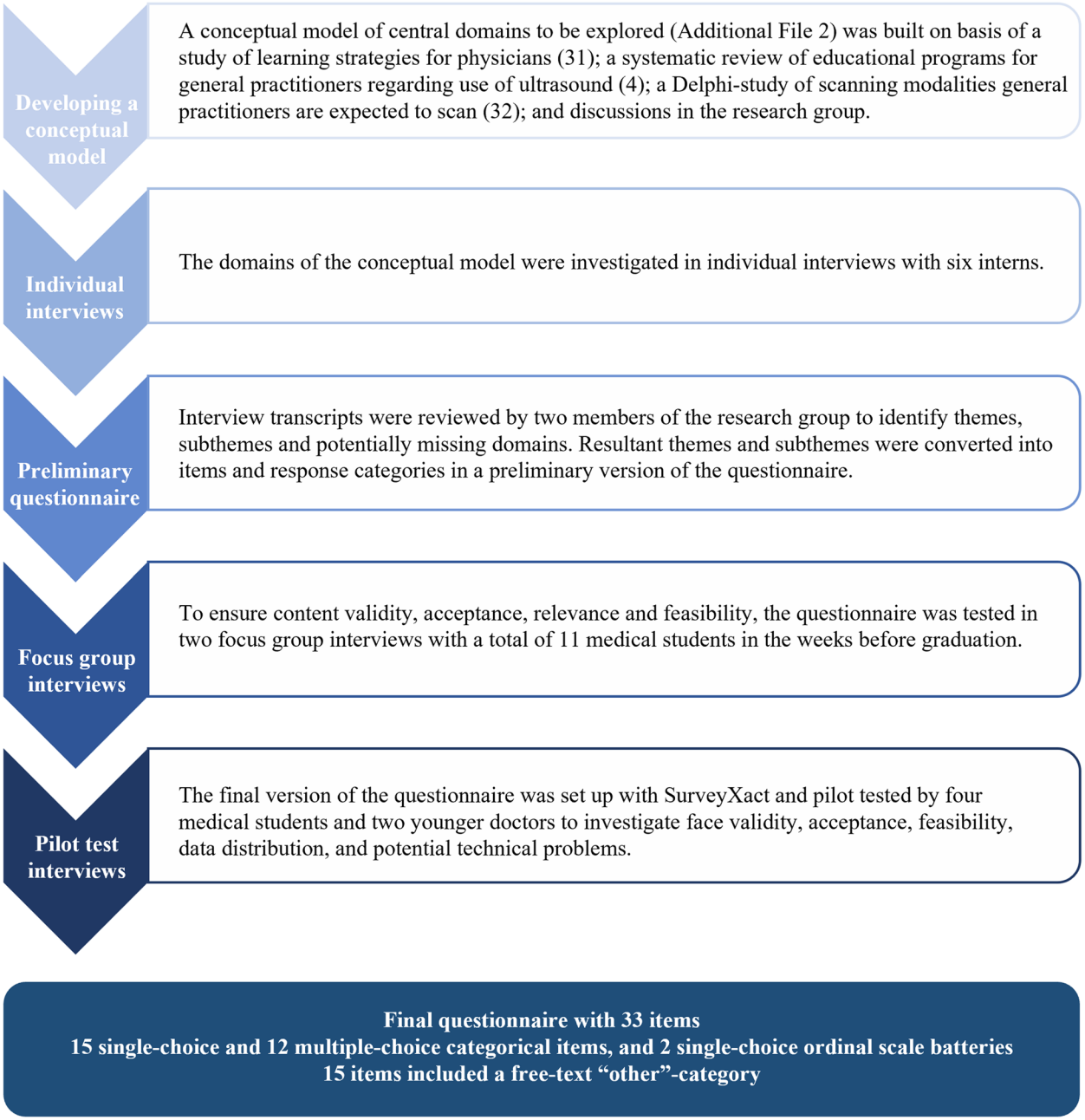

Fig. 1 Questionnaire development

and competencies obtained during medical school as well as between educational components received and competencies obtained during internships. The regression models were adjusted for age, gender, and university attended. Results are presented as relative risks. Missing data were considered random and reported for each variable. Additionally, non-completion analyses were conducted using the Fisher's Exact test, testing differences between completers and non-completers regarding internships undertaken, received ultrasound education, and expectations to future specialization. Likewise, potential differences were tested between the study sample and the background population and between pre- and during/post-2021-graduates, using the Fisher's Exact test.

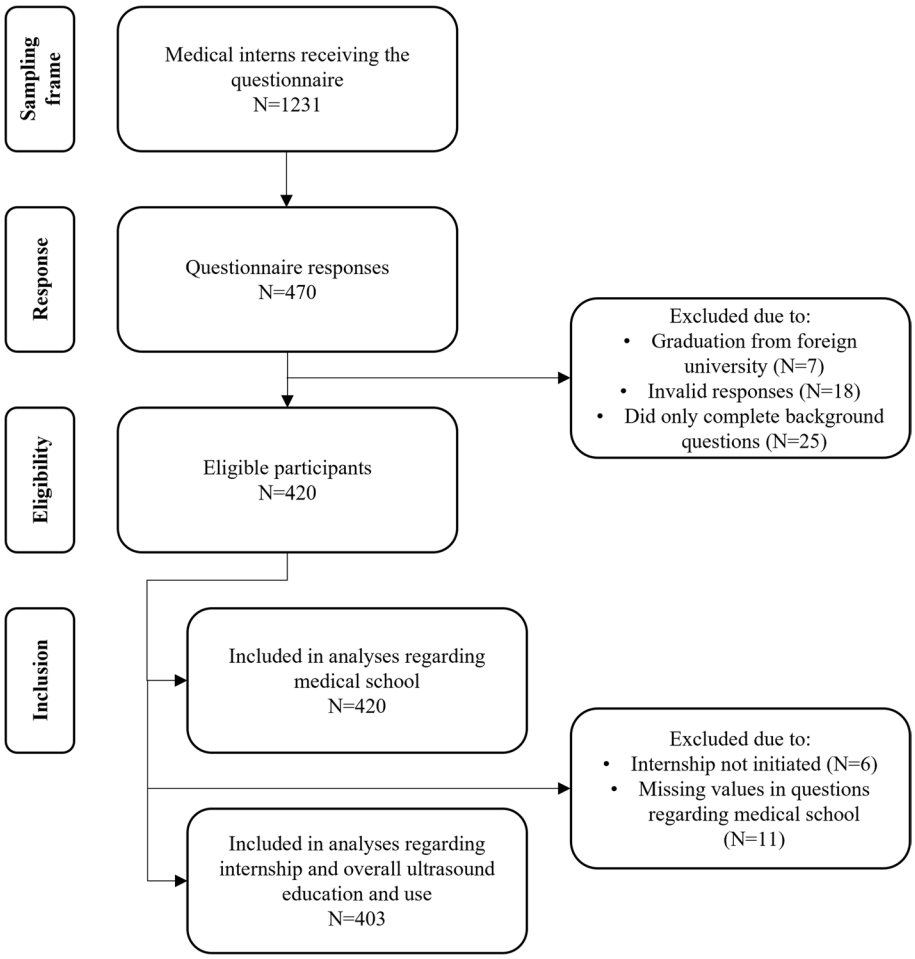

Fig. 2 Participant inclusion

Results

A total of 470 (38.2%) interns responded to the survey. Figure 2 displays participant inclusion.

Table 1 details participant characteristics. Non-completion analysis (Additional file 3) showed no significant differences in medical school items, but a few related to internship employments, formal ultrasound education, ultrasound encounters in clinical work, opportunities for using ultrasound, and expectations for future specialization. Comparison with the background population (Additional file 4) showed significant differences only in 2022 graduates' university distribution. Pre-2021 graduates only differed significantly from during/post-2021 graduates in less frequently having received e-learning and ultrasound tests (Additional file 5).

Ultrasound education: medical school

The vast majority (95.7%; CI95 93.8–97.8) received formal ultrasound education during medical school (Additional file 6). Among these, incorporation of ultrasound images in lectures (77.4%; 73.1–81.3) and practical ultrasound training (71.7%; 67.1–75.9) were most common, followed by theoretical lessons in ultrasonography (54.1%; 49.1–58.9), theoretical e-learning (33.1%; 28.6–37.8) and ultrasound demonstration (18.3%; 14.7–22.4). Only 3.8% (2.2–6.1) received no formal education, including 1.4% (0.5–3.1) reporting COVID-19 cancellations. A further 1.2% (0.4–2.8) reported ultrasound education from other engagements, including student jobs, research, or voluntary courses. Most formal ultrasound education occurred solely during the master's program (bachelor's: 3.8%, 2.2–6.1; master's: 67.9, 63.2–72.3; both: 17.4%, 13.9–21.4). Only 20.7% (16.9–24.9) had been formally tested in ultrasound during medical school.

During clinical rotations, 86.0% (83.8–90.5) encountered ultrasound: 76.9% (72.6–80.9) observed doctors scanning, 39.5% (34.8–44.4) practiced scanning healthy volunteers/phantoms/fellow students themselves, 38.3% (33.7–43.2) scanned patients themselves, and 26.0% (21.8–30.4) were taught how to use ultrasound.

Table 1 Participant characteristics

N = 420	Distribution
Age	
Range (Median; IQR)	25–48 (28; 27–30)
Missing	0 (0.0)
Gender, N (%)	
Female	290 (69.1)
Male	130 (30.9)
Other	0 (0.0)
Missing	0 (0.0)
Graduation year, medical school	
Range (Median; IQR)	2007–2023 (2021; 2021–2022)
Missing	0 (0.0)
Medical school attended (N; %)	
AAU	22 (5.2)
AU	149 (35.5)
KU	146 (34.8)
SDU	103 (24.5)
Missing	0 (0.0)
Internship employments (N; %)	
Internal medicine	130 (32.3)
Cardiology	18 (4.5)
Orthopedic surgery	46 (11.4)
Abdominal surgery	65 (16.1)
Urology	18 (4.5)
Emergency medicine	103 (25.6)
Geriatrics	5 (1.2)
Gynecology	0 (0.0)
Psychiatry	7 (1.7)
General practice	355 (88.1)
Other[a]	
Neurology	12 (3.0)
Hematology	1 (0.3)
Surgery	1 (0.3)
Missing	7 (1.7)

[a] Based on free-text responses

Conversely, 11.2% (8.3–14.6) did not encounter ultrasound during clinical rotations.

Significant differences between universities were found regarding formal education ($P=0.001$), timing hereof ($P=0.001$), ultrasound encounters during clinical rotations ($P<0.001$), and ultrasound tests ($P<0.001$) (Additional file 6).

Ultrasound education: internship

During internship, 44.2% (39.3–49.2) received formal ultrasound education: 8.9% (6.3–12.2) as compulsory courses, 15.9% (12.5–19.8) as voluntary courses, 7.9% (5.5–11.0) as compulsory theme day/seminar, 28.0% (23.7–32.7) and 3.2% (1.7–5.5) as practical training in the unit or practice, respectively. No formal ultrasound education was reported by 50.1% (45.1–55.1), and 3.0% (1.5–5.1) described informal education. Table 2 displays educational components included in the ultrasound education.

Ultrasound was encountered during clinical work by 73.2% (68.6–77.5): 69.5% (64.7–73.9) in the hospital unit, 10.4% (7.6–13.8) in general practice, and 1.5% (0.5–3.2) in a focused stay elsewhere. Opportunities to apply ultrasound were received and used by 47.6% (42.7–52.6), received but not used by 18.4% (14.7–22.5), and not received by 27.1% (22.8–31.7).

In terms of barriers for learning, opportunities to use ultrasound varied across specialties (Additional file 7). Furthermore, among participants using ultrasound ($N=192$), 21.9% (16.2–28.4) were unsupervised and 77.6% (71.0–83.2) received supervision (during scanning: 71.9%, 64.9–78.1; via images/videos: 23.4%, 17.6–30.1). Of supervised interns ($N=149$), 11.4% (6.8–17.6) always received supervision, 36.2% (28.5–44.5) sometimes, 12.8% (7.9–19.2) occasionally, 29.5% (22.3–37.5) only if seeking supervision, and 7.4% (3.7–12.8) only when finding capable colleagues. Most (91.8%, 88.7–94.3) experienced barriers for using ultrasound, including insufficient scanning routine (70.5%, 65.8–74.9), lack of supervision (46.7%, 41.7–51.7), insufficient knowledge (41.4%, 36.6–46.4), time constraints (37.0%, 32.2–41.9), no impact on patient management (24.8%, 20.7–29.3), ultrasound not being standard unit practices (24.1%, 20.0–28.5), not feeling capable despite training/education (23.8%, 19.7–28.3), no scanner in the unit/practice (21.1%, 17.2–25.4), lacking mental surplus (16.6%, 13.1–20.6), unfamiliarity with the available scanner (16.4%, 12.9–20.4), uncertainty regarding when/which patients to scan (9.7%, 7.0–13.0), and scanner unavailable when needed (5.0%, 3.1–7.6). Few reported no interest in ultrasound or none of the above (3.2%, 1.7–5.4, and 2.2%, 1.0–4.2, respectively). Many (68.5%, 63.7–73.0) had to independently pursue ultrasound training (extent; very high: 25.3%, 21.1–29.9; high: 22.3%, 18.4–26.7; some: 15.9%, 12.5–19.8; lesser: 5.0%, 3.1–7.6; missing: 26). Only 10.7% (7.8–14.1%) did not.

Selected ultrasound applications

Overall, 86.4% (82.6–89.6) received training in at least one anatomical structure, while 4.5% (2.7–6.0) reported no training in any listed structures (Fig. 3). Self-rated scanning competence varied across structures from 3.7% (2.1–6.1) for thyroid and pancreas to 53.3% (48.3–58.3) for bladder (Fig. 3).

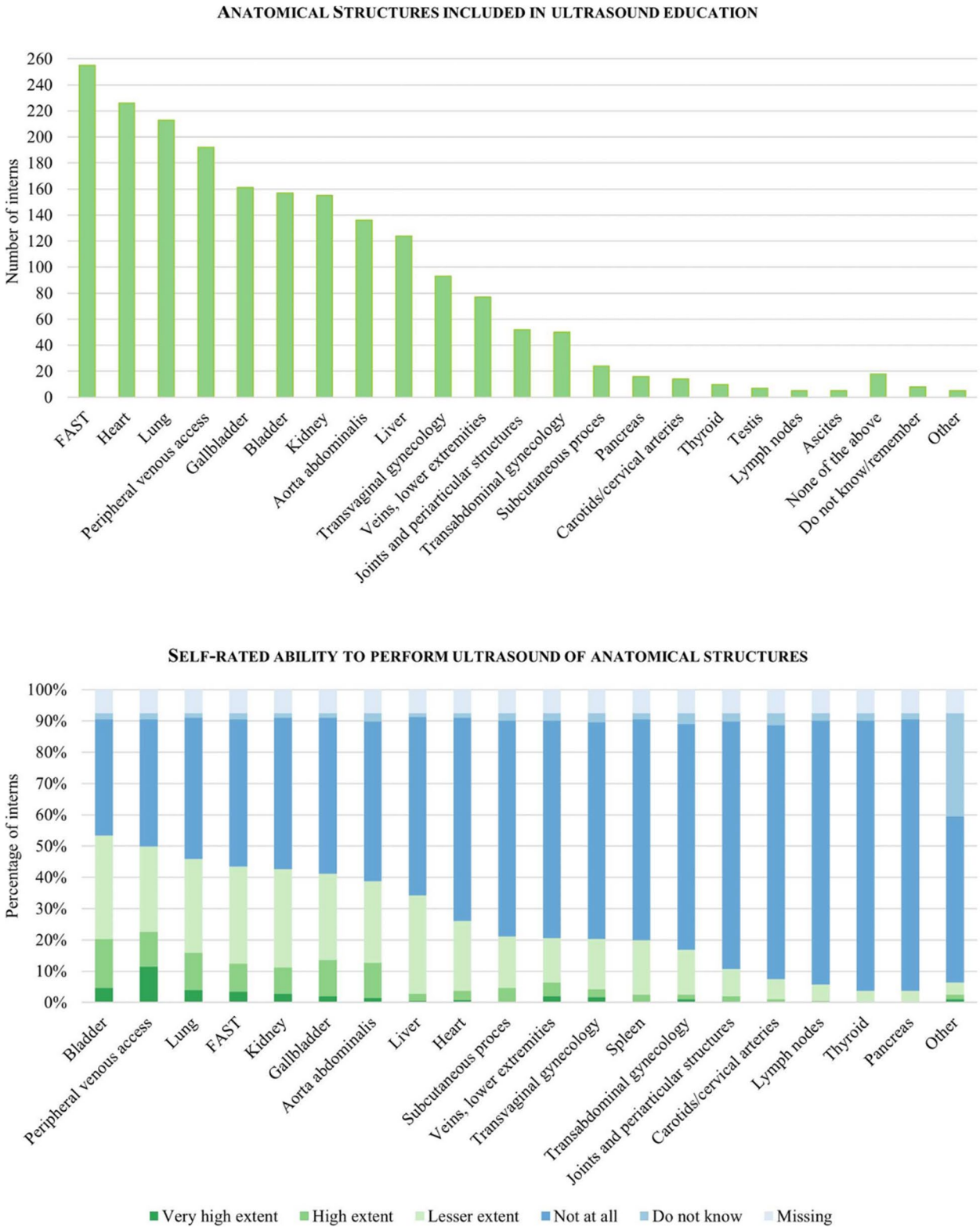

Fig. 3 Selected ultrasound applications across medical education

	Yes, very high extent	Yes, high extent	Yes, some extent	Yes, lesser extent	No	No, but elsewhere*	Do not know	Missing
Obtained theoretical or practical competencies, N (%)								
During medical school	22 (5.2)	39 (9.3)	99 (23.6)	156 (37.1)	72 (17.1)	20 (4.8)	3 (0.7)	9 (2.1)
AAU (N=22)	1 (4.6)	3 (13.6)	9 (40.9)	7 (31.8)	1 (4.6)	0 (0.0)	0 (0.0)	1 (4.6)
AU (N=149)	1 (4.6)	6 (4.0)	43 (28.9)	76 (51.0)	13 (8.7)	5 (3.4)	1 (0.7)	4 (2.7)
CPH (N=146)	2 (1.4)	3 (2.1)	35 (24.0)	60 (41.1)	31 (21.2)	10 (6.9)	2 (1.4)	3 (2.1)
SDU (N=103)	18 (17.5)	27 (26.2)	12 (11.7)	13 (12.6)	27 (26.2)	5 (4.9)	0 (0.0)	1 (1.0)
P-value**								<0.001
During internship	33 (8.2)	38 (9.4)	78 (19.4)	74 (18.4)	142 (35.2)	9 (2.2)	2 (0.5)	27 (6.7)
Received sufficient ultrasound education in…, N (%)								
Ultrasound physics	22 (5.5)	62 (15.4)	118 (29.3)	83 (20.6)	80 (19.9)	N/A	4 (1.0)	34 (8.4)
Technical formation of ultrasound images	19 (4.7)	83 (20.6)	92 (22.8)	82 (20.4)	91 (22.6)		2 (0.5)	34 (8.4)
Optimization of ultrasound images	23 (5.7)	68 (16.9)	100 (24.8)	77 (19.1)	98 (24.3)		3 (0.7)	34 (8.4)
Practical performance of different scans	20 (5.0)	66 (16.4)	108 (26.8)	87 (21.6)	85 (21.1)		3 (0.7)	34 (8.4)
Interpretation of ultrasound images	12 (3.0)	68 (16.9)	128 (31.8)	90 (22.3)	70 (17.4)		1 (0.3)	34 (8.4)
Distinguishing between normal/not normal	9 (2.2)	38 (9.4)	113 (28.0)	102 (25.3)	106 (26.3)		1 (0.3)	34 (8.4)
Indications for ultrasound use	28 (7.0)	103 (25.6)	123 (30.5)	63 (15.6)	51 (12.7)		1 (0.3)	34 (8.4)
Sources of error	7 (1.7)	40 (9.9)	109 (27.1)	107 (26.6)	103 (25.6)		3 (0.7)	34 (8.4)
Integration of ultrasound in clinical decision-making	20 (5.0)	87 (21.6)	99 (24.6)	82 (20.4)	79 (19.6)		2 (0.5)	34 (8.4)
Consequences of ultrasound	17 (4.2)	57 (14.1)	92 (22.8)	96 (23.8)	101 (25.1)		6 (1.5)	34 (8.4)
Would have liked more ultrasound education, N (%)								
During medical school	217 (51.7)	99 (23.6)	68 (16.2)	10 (2.4)	13 (3.1)	N/A	2 (0.5)	11 (2.6)
During internship	209 (51.9)	94 (23.3)	51 (12.7)	7 (1.7)	12 (3.0)		3 (0.7)	27 (6.7)

* Student jobs, research activities, and/or voluntary course activity were elaborated by 10 participants when asked about medical school, and by 8 when asked about internship.
** Differences between universities regarding competencies obtained (yes/no) were examined with the Fisher's Exact test

0-25%
26-50%
51-75%
76-100%

Fig. 4 Evaluation of received ultrasound education

Evaluation of ultrasound education

Overall, 75.2% (70.8–79.3) and 55.3% (50.3–60.3) reported gaining scanning competency from medical school and internship, respectively (Fig. 4). However, competencies were mainly acquired to lesser/some extent, and nearly all desired more ultrasound education (medical school: 93.8%, 91.1–95.9; internship: 89.6%, 86.2–92.4). Sufficient education was likewise predominantly reported to lesser/some extent. The educational aspect most frequently deemed sufficient was education in the indications for ultrasound (Yes, total: 78.7%, 74.3–82.6), followed by interpretation of ultrasound images (74.0%, 69.4–78.2), integration of ultrasound in clinical decision-making (71.5%, 66.8–75.8), ultrasound physics (70.7%, 66.0–75.1), practical performance of different scans (69.7%, 65.0–74.2), technical formation of ultrasound images (68.5%, 63.7–73.0), optimization of ultrasound images (66.5%, 61.7–71.1), sources of error (65.3%, 60.4–69.9), consequences of ultrasound (65.0%, 60.1–69.7), and training in distinguishing normal from abnormal (65.0%, 60.1–69.7).

Efforts most frequently expected to improve scanning competence were ultrasound courses during internships, scanning more patients, and more supervision, accounting for 81.4% (77.2–85.1), 75.7% (71.2–79.8), and 61.8% (56.8–66.6), respectively. Next was more teaching on pathological findings (55.6%, 50.6–60.5), more education during medical school (54.3%, 49.3–59.3), and more teaching on normal findings (42.7%, 37.8–47.7), consequences of pathological findings (29.5%, 25.1–34.2) and scanning indications (26.8%, 22.5–31.4). Three reported 'other' and elaborated: post-course e-learning, regular simulation training, focused teaching during internship, more time, and encouragement from attending physicians to scan. Two reported no further needs. There were 37 missing values.

Expectations of future ultrasound usage

Expectations of future ultrasound use were positive (Additional file 8). The majority (71.0%, 66.3–75.4) anticipated using ultrasound, 9.2% (6.5–12.4) did not, and 10.4% (7.6–13.8) were unsure. Most believed ultrasound should be a core competence for all interns (yes: 73.0%, 68.3–77.2; no: 4.5%, 2.7–7.0; individual choice: 8.2%, 5.7–11.3; unsure: 5.0%, 3.1–7.6). There were 38 missing values.

Tendencies for perceiving ultrasound competence

Competency acquisition in medical school correlated significantly with receiving practical or both theoretical and practical education, but not with theoretical education alone (Table 2). Additionally, having been tested in ultrasound correlated significantly with competency acquisition in medical school. Among recipients of formal ultrasound education during internships, significant associations were found between obtained competencies

Table 2 Tendencies in perceived ultrasound competence acquisition

		Unadjusted model			Adjusted model[a]		
	N (%)	RR	CI95	*P*-value[b]	RR	CI95	*P*-value[b]
Types of ultrasound education in medical school[c]							
Theoretical	100 (23.8)	2.22	0.79–6.27	0.131	2.16	0.76–6.10	0.148
Practical	23 (5.5)	4.32	1.55–12.06	**0.005**	4.08	1.45–11.43	**0.008**
Both theoretical and practical	278 (66.2)	4.63	1.68–12.76	**0.003**	4.34	1.57–12.02	**0.005**
Missing	3 (0.7)						
Tests in ultrasound in medical school[c]							
Tested in ultrasound	87 (20.7)	1.32	1.21–1.43	**< 0.001**	1.55	1.35–1.77	**< 0.001**
Do not know/remember	38 (9.1)	1.01	0.82–1.24	0.955	1.05	0.86–1.29	0.614
Missing	7 (1.7)						
Educational components in ultrasound received during internship[c]							
E-learning/online material	67 (37.6)	1.01	0.95–1.09	0.683	0.98	0.92–1.05	0.608
Books/encyclopedia	2 (1.1)	1.06	1.02–1.10	**0.003**	1.07	1.01–1.14	**0.033**
Theoretical lessons	69 (38.8)	0.99	0.92–1.07	0.823	0.99	0.92–1.06	0.709
Theoretical teaching bedside	100 (56.2)	1.06	0.98–1.15	0.149	1.06	0.98–1.14	0.138
Practical training on phantoms	33 (18.5)	1.03	0.96–1.11	0.427	1.02	0.95–1.10	0.560
Practical training on healthy volunteers	109 (61.2)	0.99	0.92–1.07	0.857	0.97	0.90–1.05	0.455
Practical training on patients	104 (58.4)	1.09	1.00–1.19	**0.044**	1.09	1.00–1.19	**0.038**
Requirements for number of scans	19 (10.7)	1.06	1.02–1.11	**0.003**	1.06	1.00–1.12	**0.035**
Test(s) of competence	23 (12.9)	1.07	1.02–1.11	**0.003**	1.06	1.01–1.11	**0.020**
Other:							
Education was not formal[e]	1 (0.6)						
Do not know/remember	0 (0.0)						
Missing	5 (2.8)						
Number of educational components in ultrasound received during internship[d]							
One component	36 (20.9)						
Two components	48 (27.9)	1.03	0.90–1.18	0.644	1.03	0.91–1.17	0.598
Three components	31 (18.0)	1.03	0.89–1.19	0.721	1.01	0.89–1.14	0.893
Four or more components	57 (33.1)	1.08	0.96–1.21	0.181	1.06	0.97–1.16	0.222

[a] Adjusted for age, gender, and university attended

[b] Modified Poisson regression

[c] Comparator: None received

[d] Comparator: One component

[e] Based on free-text response

and practical training on patients, required scan numbers, evaluated scanning competency, and consulting books/encyclopedia. Competence acquisition did not correlate significantly with receiving multiple educational components versus one.

Discussion

Principal findings

This study showed that ultrasound training is part of the Danish medical school curriculum, as 95.7% of the participants had received formal ultrasound training and 86.0% encountered ultrasound examinations during clinical rotations. However, extent and type of training varied across universities and seemed to develop over time. Ultrasound training was less integrated during the internship year where ultrasound examinations were encountered by 73.2% and performed by 47.6%, while 44.2% received formal ultrasound training and 68.5% had to pursue training themselves. Several barriers for interns' ultrasound usage were reported, including lack of scanning routine and supervision, insufficient knowledge and confidence, time constraints and lack of mental surplus. Accordingly, participants frequently considered ultrasound courses during the internship, scanning more patients, and receiving more supervision would have improved their ultrasound skills.

Most reported competence gain and sufficient education to lesser/some extent and 93.8% and 89.6% called for more ultrasound training during medical school and internship, respectively. Indeed, 71.0% expected using ultrasound in their future work and 73.0% considered it a core competence. Associations were found between perceived scanning competence and structured educational components, e.g., tests.

Interpretation in relation to other studies

Our findings confirm previous papers describing that ultrasound education has been implemented in medical schools, but without curricular uniformity [6, 8, 10, 16]. Guidelines for medical school ultrasound training [2, 6, 13] outline needs for both theoretical and practical training, but our results show that this is not fully incorporated. Recent studies have highlighted the benefits of peer-to-peer teaching [35], e-learning [36], and simulation-based training [35] to increase learning outcomes and reduce faculty-resources and labor-intensive teaching. Our results, however, show that such methods were not commonly used in Danish Universities.

As ultrasound training can enhance medical students' understanding of anatomy and physiology [11, 15], the lack of training may represent missed opportunities for these benefits. Also, with varied levels of training, medical students will have different qualifications and starting points for applying ultrasound when entering their internship, possibly challenging integration of standardized ultrasound training in internship and residency programs. Although, post-course skills assessment is recommended and known to increase motivation and retention [37], only 20.7% of participants remembered being tested in ultrasound during medical school, and most participants found the ultrasound education during medical school only provided them a low level of scanning competence. Indeed, 93.8% wanted to have had more ultrasound training. This may be explained by the large interest in POCUS among medical students [11, 38] and junior doctors [39] or a perceived need resulting from frequently encountering ultrasound in emergency departments and admissions wards [40].

In addition to variations in amount and type of training provided, several barriers were identified for using ultrasound during the internship year, including having to independently take the initiative, insufficient supervision, and insecurity in own abilities. This mirrors identified barriers for resident ultrasound training in America [41–44]. Our study further suggests that experienced high workload and lack of mental surplus may be of influence. Newly graduated doctors have a high workload and must develop competencies within several areas during their internship [45], and the lack of a defined core ultrasound curriculum during internship may prone these doctors to give ultrasound skills lower priority, despite their interest and motivation. Hence, organizational scaffolding may be needed to ensure adequate ultrasound training. Implementation hereof is previously found challenged by lack of qualified faculty teachers and ultrasound equipment [10, 17, 42, 44], but the importance of these factors may be transient. Meanwhile, alternatives like e-learning, focused teaching sessions outside the department, or peer-to-peer teaching may suffice [11, 35, 46]. Traditional teaching methods such as lectures cannot stand alone [35], and restricting teaching to short practical sessions is insufficient as scanning competence develops over time and requires practice [2, 47]. Continuous exposure to ultrasound is therefore paramount. Starting early – possibly in medical school – with a scaffolded educational plan continuously offering support while gradually increasing complexity fosters skill development [8, 48], a solid foundation of knowledge, and students moving towards self-directed learning [6, 49], possibly making ultrasound training less resource-intensive during internship. Ultimately, departments and patients may benefit from interns with ultrasound skills acquired during medical school.

In this study, we found associations between perceived scanning competence and having received structured educational components such as practical training sessions during medical school, practicing on patients during internship, consulting structured learning sources, requirements for number of performed scans, and tests. Although self-perceived skills may be an unreliable measure of competence [19], these findings support previous training recommendations highlighting the importance of structured theoretical and practical introduction, continuous practice followed by skills assessment. The results further suggests that training governance also creates a sense of certainty for the individual.

Strengths and limitations

With a 38.2% response rate and 14.8% non-completion, selection bias may be a risk, potentially overrepresenting ultrasound interested interns. Surveying doctors however commonly yield low response rates [50, 51]. Selection bias risk is not ruled out, but mitigated through cinema ticket incentives, non-completion analysis revealing only few differences, and background characteristics of participants generally aligning with Denmark's medical school graduates. Comparison with interns' background population was unfeasible. Recall bias risk in medical school items is deemed minimal as pre-2021 and during/post-2021 graduates only differed significantly regarding e-learning and ultrasound tests. This may be expected following COVID-19 and increasing ultrasound usage,

respectively. Hence, there may be biases not adjusted for. Lack of valid data on internship initiation and completion hindered analyses of differences across internship progression states. Given potentials for attaining additional ultrasound education and skills during later stages, education and competencies acquired may be underestimated. Conversely, the self-assessment of ultrasound competencies poses risk of overestimation [52]. While regional variations regarding, e.g., POCUS usage and curricular ultrasound [53] may limit generalizability internationally, findings from the Danish context can exemplify current ultrasound education and competencies prior to residency initiation.

Implications for research and practice

The participants in this study wanted more ultrasound training but filled curricula in medical school and internship pose dilemmas for prioritization. Discrete choice experiments may be used to explore which skills in the curriculum should be deselected to give way for ultrasound.

This study demonstrates barriers for junior doctors to use ultrasound during internships. They thereby miss opportunities for building scanning routine and for maintaining and/or building upon competencies obtained in medical school, which departments and patients then cannot benefit from. Hence, efforts must be made to scaffold and structure continuous learning, creating a solid and uniform foundation for later residency training.

Conclusions

This study demonstrates that ultrasound training is part of medical school curricula but varies in terms of type and extent, not fully meeting recommendations for providing both practical and theoretical training. While many encountered ultrasound examinations during internships, formal training was less integrated, and many had to pursue training independently. The majority reported competence gain from both medical school and internship, but mainly to lesser/some extent. Several barriers for using ultrasound were identified, the most frequent being insufficient scanning routine, supervision and knowledge – reflecting the interns' opinions regarding what would have improved their competencies, namely ultrasound courses, scanning more patients and receiving more supervision. The interns generally expected using ultrasound in their future work and considered it a core competence. Finally, we found associations between perceived scanning competencies and structured educational components, e.g., tests, suggesting a need for training governance.

Abbreviations

POCUS	Point-of-care ultrasound
WFUMB	The World Federation for Ultrasound in Medicine and Biology
AAU	Aalborg University
AU	Aarhus University
CPH	University of Copenhagen
SDU	University of Southern Denmark

Supplementary Information

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Additional file 1.
Additional file 2.
Additional file 3.
Additional file 4.
Additional file 5.
Additional file 6.
Additional file 7.
Additional file 8.

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Authors' contributions

The named authors have made substantial contributions to the study, as well as drafting the article and revising it critically for important intellectual content. The study was designed by TP, CAA and MBJ in collaboration. The preceding interviews were conducted and analyzed by TP and CAA. The questionnaire was developed by TP, CAA and MBJ, and CAA had the responsibility of data collection. EE, SS, SW and KA did the initial data cleansing and analysis, while the final data cleansing and analysis was done by PG. PG and CAA wrote the first draft of the article.

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Data availability

The anonymized transcriptions from the interviews, the collected survey-responses and the analytic datasets are available stored at Center for General Practice at Aalborg University, Denmark, according to regulations by the Danish Data Protection Agency. Anonymized data are available upon reasonable request by contacting the corresponding author.

Declarations

Ethics approval and consent to participate

The study was performed in accordance with the Declaration of Helsinki. According to Danish law (komitélovens § 14, stk. 2), no ethical approval was needed for this project.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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