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Point-of-care ultrasound training for residents in anaesthesia and critical care: results of a national survey comparing residents and training program directors' perspectives

Silvia Mongodi^{1,2*}, Francesca Bonomi^{3†}, Rosanna Vaschetto^{4,5}, Chiara Robba^{6,7}, Giulia Salve^{1,8}, Carlo Alberto Volta⁹, Elena Bignami¹⁰, Luigi Vetrugno^{11,12}, Francesco Corradi^{13,14}, Salvatore Maurizio Maggione^{11,12}, Paolo Pelosi^{6,7} and Francesco Mojoli^{1,8}

Abstract

Background: Point-of-care ultrasound (POCUS) has become an essential tool for anaesthesia and critical care physicians and dedicated training is mandatory. This survey describes the current state of Italian residency training programs through the comparison of residents' and directors' perspective.

Methods: Observational prospective cross-sectional study: 12-question national e-survey sent to Italian directors of anaesthesia and critical care residency programs ($N = 40$) and residents ($N = 3000$). Questions focused on POCUS teaching (vascular access, transthoracic echocardiography, focused assessment for trauma, transcranial Doppler, regional anaesthesia, lung and diaphragm ultrasound), organization (dedicated hours, teaching tools, mentors), perceived adequacy/importance of the training and limiting factors.

Results: Five hundred seventy-one residents and 22 directors completed the survey. Bedside teaching (59.4–93.2%) and classroom lessons (29.7–54.4%) were the most frequent teaching tools. Directors reported higher participation in research projects ($p < 0.05$ for all techniques but focused assessment for trauma) and simulation ($p < 0.05$ for all techniques but transthoracic echocardiography). Use of online teaching was limited ($< 10\%$); however, 87.4% of residents used additional web-based tools. Consultants were the most frequent mentors, with different perspectives between residents (72.0%) and directors (95.5%; $p = 0.013$). Residents reported self-training more frequently (48.5 vs. 9.1%; $p < 0.001$). Evaluation was mainly performed at the bedside; a certification was not available in most cases ($< 10\%$). Most residents perceived POCUS techniques as extremely important. Residents underestimated the relevance given by directors to ultrasound skills in their evaluation and the minimal number of exams required to achieve basic competency. Overall, the training was considered adequate for vascular access only (62.2%). Directors mainly agreed on the need of ultrasound teaching improvement in all fields. Main limitations were the absence of a standardized curriculum for residents and limited mentors' time/expertise for directors.

[†]Silvia Mongodi and Francesca Bonomi contributed equally to this work.

*Correspondence: silvia.mongodi@libero.it

² Rianimazione I, Fondazione IRCCS Policlinico S. Matteo, DEA piano -1, Viale Golgi 19, 27100 Pavia, Italy

Full list of author information is available at the end of the article



Conclusion: POCUS education is present in Italian anaesthesia and critical care residency programs, although with potential for improvement. Significant discrepancies between residents' and directors' perspectives were identified.

Keywords: Point-of-care ultrasound, Ultrasound education, Training, Residency school organization, Ultrasound curriculum, Teaching

Background

Ultrasound is a bedside non-irradiating tool and is now easily available in hand-held devices; it allows integrative head-to-toe clinical assessment as well as guidance for invasive procedures. For these reasons, ultrasound has recently become ever more present in the hands of anaesthesia and critical care physicians [1]. Anaesthesiologists and intensivists' ultrasound skills started with intraoperative transoesophageal echocardiography [2], but rapidly spread to vascular access [3] and regional anaesthesia [4]. In critical care, the last few decades showed an increase in point-of-care ultrasound (POCUS) [5] for hemodynamic [6], respiratory [7, 8] and neurologic assessment [9]. POCUS has also become helpful for assessing trauma patients [10], making a differential diagnosis in acute respiratory failure [11], redirecting treatment [12] and replacing traditional imaging [13, 14]. Each ultrasound technique requires adequate training, since POCUS can be misleading when performed by inexperienced operators [15]. Skill levels and corresponding minimum requirements for training have been established for brain [16], lung [17, 18] and cardiac [19] ultrasound and for ultrasound-guided procedures [20]; this was the starting point to define dedicated training pathways for intensivists and anaesthesiologists [21, 22]. However, recent studies showed remarkable heterogeneity in ultrasound training programs all around the world [23–30] and the need for a standardized ultrasound training program remains a relevant issue [24, 31]. The purpose of this survey was to describe the current state and limitations of ultrasound training in Italian anaesthesia and critical care residency programs; the identification of weaknesses and strengths from two different points of view (training program directors and residents) was considered a first step to improve the education system and to structure a national ultrasound curriculum for intensivists and anaesthesiologists.

Methods

This is an observational prospective cross-sectional study: following accepted research practices for surveys [32, 33], we conducted a closed e-survey on the ultrasound training programs for vascular access (VA), lung ultrasound (LUS), transthoracic echocardiography (TTE), focused-assessment for trauma (FAST),

transcranial Doppler (TCD), regional anaesthesia (RA) and diaphragm ultrasound (DUS) during the 5-year residency school in anaesthesia and critical care residency schools in Italy. Residency schools in Italy are university entities responsible for teaching and training medical residents. The survey included questions on the teaching organization (number of hours for theoretical training, teaching tools, availability of tutors devoted to each ultrasound field), perceived adequacy and importance of the training, limiting factors and potential improvements. The ethical committee (Comitato Etico Pavia) of the Fondazione IRCCS Policlinico S. Matteo waived the need for ethics approval and consent to participate. The study was approved and supported by the College of Professors in Anaesthesiology and Critical Care (CPAR).

Sampling

The same 12-question e-survey was sent to two target populations via e-mail by the Italian CPAR to recruit directors of residency programs ($N=40$) who were then asked to send the survey link to their residents (estimated number = 3000). Five more questions were added to residents' survey to investigate their use of additional learning tools. The survey remained accessible from October 2018 until December 2019; once sent, the responders were not able to review and change their answers. Data were not stored if the survey was not completed (participation rate = completion rate).

Questionnaire

The survey included open and closed questions (both multiple choice and Likert-like questions – e-Appendix 1 and 2); it was implemented using a Google form which provided an intuitive interface and automatic data export. Adequacy of contents, correct functioning of the form, and quick filling time (less than ten minutes) were tested on a sample of 20 students before the beginning of the study. Residents' responses were collected anonymously; though the survey asked which school the residents and directors belonged to, as a way to analyse geographic distribution, facilitate personalized follow-up calls and identify duplicates, this information was not further analysed. Follow-up e-mails were sent 4 times to directors, while no direct contact was available with residents. There were no incentives for participation.

Statistical analysis

Data are displayed as numbers and percentages. Comparisons between directors' and residents' answers were performed by Fisher's exact test. Comparisons excluded answers like "I don't know" / "not yet encountered in my training path" since expected in residents' answers only. Analysis was performed by STATA SE 14 for Macintosh.

Results

Sample of survey respondents

We obtained 22/40 answers from directors (26 actual answers, 4 duplicates, response rate 55.0%); 3/6 were from Southern Italy, 3/8 from Central Italy, 14/18 from Northern Italy, 2/5 from the islands. 571 residents from 30 residency schools filled in the survey (75.0% of residency schools represented, overall response rate 19.0%); 95 (16.6%) were from Southern Italy, 54 (9.5%) from Central Italy, 410 (71.8%) from Northern Italy and 12 (2.1%) from the islands. Northern Italy resulted to be more represented; however, it also holds 45.0% of the residency schools. Residents were homogeneously distributed among the five years of residency school (first 18.0%, second 20.1%, third 21.4%, fourth 24.2%, fifth 16.3%). 21 schools were represented by both residents and directors; in 1 case, we only received director's answer. In a

minority of cases, schools were represented by residents only (65 residents, 10 schools – e-Fig. 1).

Teaching organization

The teaching tools used for ultrasound training are displayed in Table 1. Bedside teaching was the most frequently used for all ultrasound techniques. A significant difference between residents' and directors' point of view was observed for FAST (57.9 vs. 86.4%; $p=0.007$) and DUS (59.4 vs. 81.8%; $p=0.043$). The second most frequently used tool was classroom lessons (i.e., teacher-centred instruction taking place from the front of the classroom) but with lectures reported as more frequent and longer in hours by directors for all the ultrasound techniques (Fig. 1). A higher participation in research projects was reported by directors for all techniques but FAST ($p<0.005$). Simulation was not frequently used, yet with a different perception by residents and directors for VA (19.2 vs. 45.5%; $p=0.006$), FAST (9.6 vs. 27.3%; $p=0.019$) and TCD (5.3 vs. 18.2%; $p=0.035$). Online modules were used in <10% of cases, according to both directors and residents. Residents reported the use of additional learning tools like web-based teaching (webinars, tutorials, videos – 87.4%), books and scientific literature (79.9%), extra-curricular courses (52.4%) and others (5.3%). According to residents, 55.9% attended an

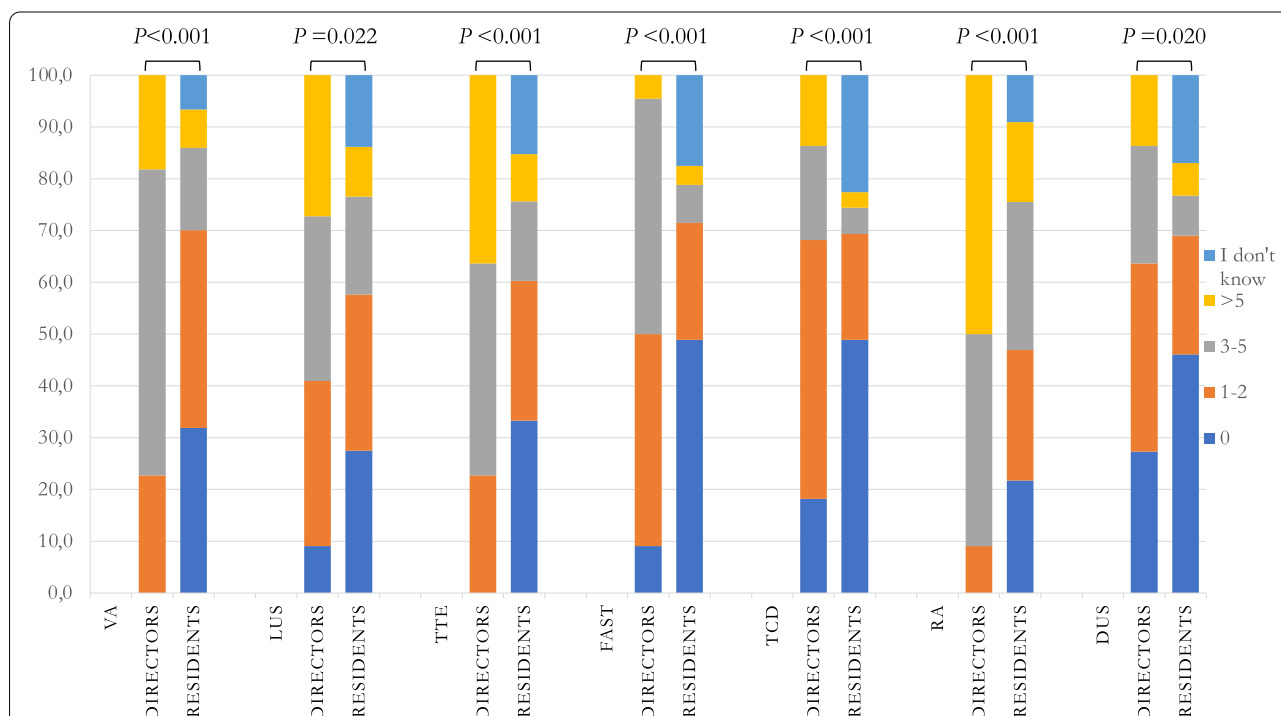


Fig. 1 Hours dedicated to each technique along the 5 years of residency school according to directors and residents. VA: vascular access; LUS: lung ultrasound; TTE: transthoracic echocardiography; FAST: focused assessment with sonography in trauma; TCD: transcranial Doppler; RA: regional anaesthesia; DUS: diaphragm ultrasound. The comparison excluded those answering: "I don't know", being expected among residents only

Table 1 Teaching tools adopted for different ultrasound techniques

	Bedside teaching			Online modules			Classroom lessons			Simulation			Research			None			Not yet encountered in my training		
	R	D	P value	R	D	P value	R	D	P value	R	D	P value	R	D	P value	R	D	P value	R	D	P value
	VA	520 (93.2)	21 (95.5)	1.000	22 (3.9)	2 (9.1)	0.230	204 (36.6)	18 (81.8)	<0.0001	107 (19.2)	10 (45.5)	0.006	34 (6.1)	7 (31.8)	<0.0001	19 (3.49)	0 (0.0)	1.000	13	
LUS	426 (84.4)	18 (81.8)	0.764	36 (7.1)	0 (0.0)	0.388	232 (45.9)	15 (68.2)	0.049	67 (13.3)	6 (27.3)	0.104	88 (17.4)	11 (50.0)	0.001	29 (5.7)	1 (4.5)	1.000	66		
TTE	356 (74.3)	20 (90.9)	0.127	27 (5.6)	0 (0.0)	0.623	205 (42.8)	14 (63.6)	0.077	43 (9.0)	4 (18.2)	0.141	40 (8.4)	5 (22.7)	0.038	60 (12.5)	0 (0.0)	0.097	92		
FAST	259 (57.9)	19 (86.4)	0.007	25 (5.6)	0 (0.0)	0.621	130 (29.1)	15 (68.2)	<0.0001	43 (9.6)	6 (27.3)	0.019	11 (2.5)	2 (9.1)	0.120	119 (26.6)	1 (4.5)	0.022	124		
TCD	256 (61.8)	15 (68.2)	0.655	27 (6.5)	0 (0.0)	0.384	123 (29.7)	14 (63.6)	0.002	22 (5.3)	4 (18.2)	0.035	33 (8.0)	6 (27.3)	0.009	102 (24.6)	3 (13.6)	0.312	157		
RA	459 (86.4)	22 (100)	0.097	36 (6.8)	1 (4.5)	1.000	289 (54.4)	19 (86.4)	0.003	87 (16.4)	5 (22.7)	0.390	35 (6.6)	7 (31.8)	0.001	25 (4.7)	0 (0.0)	0.616	40		
DUS	266 (59.4)	18 (81.8)	0.043	31 (6.9)	1 (4.5)	1.000	151 (33.7)	14 (63.6)	0.006	39 (5.7)	3 (13.6)	0.434	92 (20.5)	14 (63.6)	<0.0001	108 (24.1)	3 (13.6)	0.315	123		

Data are displayed as values (percentage). In bold: statistically significant p values for comparison between residents and directors for each ultrasound technique and teaching tool; Fisher exact and percentages were computed excluding those answering: "Not yet encountered in my training" in residents' answers

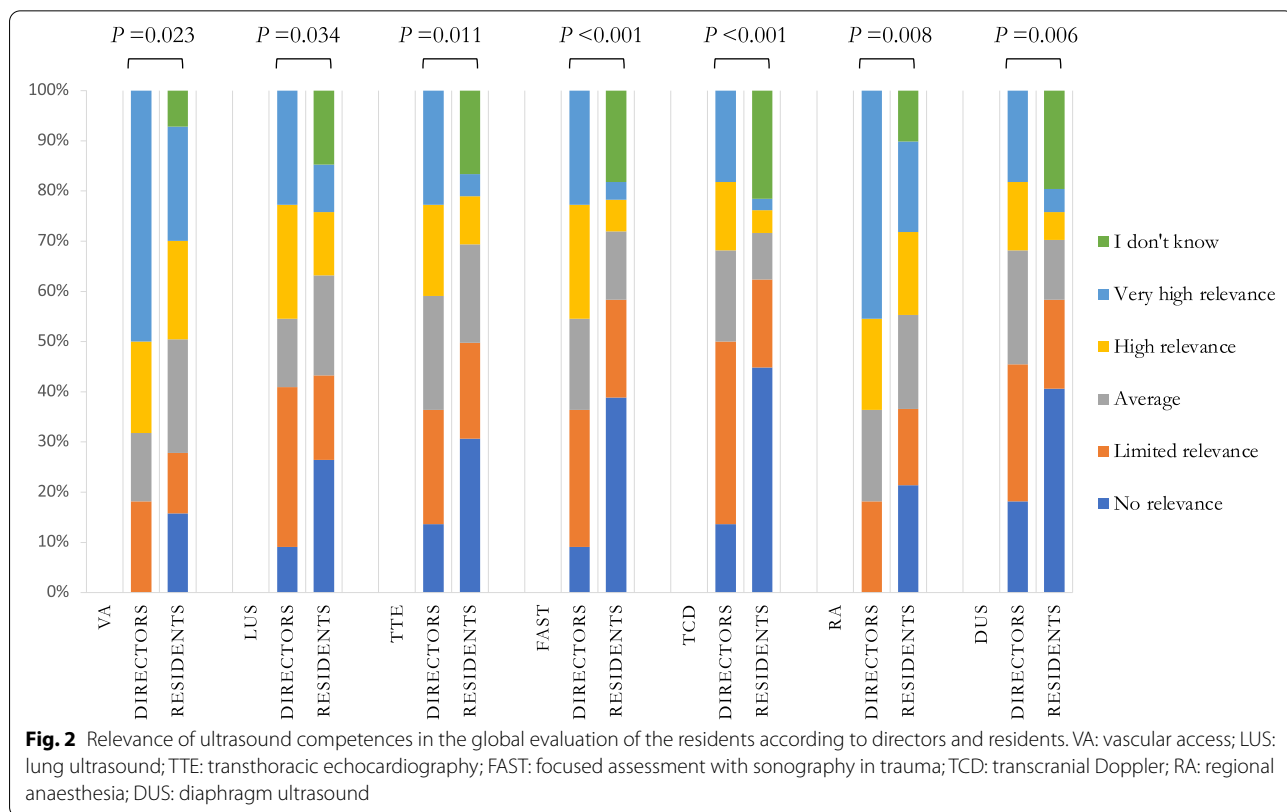
R Residents, D Directors, VA Vascular access, LUS Lung ultrasound, TTE Transthoracic echocardiography, FAST Focused assessment with sonography in trauma, TCD Transcranial Doppler, RA Regional anaesthesia, DUS Diaphragm ultrasound

extra-curricular ultrasound course (*i.e.*, a course external to the residency school requiring financial support); 14.5% were sponsored by the residency school. 77.3% of directors reported to have supported at least 25% of residents for an extra-curricular ultrasound course. Consultant physicians were the most frequent mentors, however with a significantly different perception (residents' point of view: 72.0 vs. directors' point of view: 95.5%; $p=0.013$ – e-Fig. 2). Residents reported self-training as more frequent (48.5 vs. 9.1%; $p<0.001$). In 12.3 (VA) to 29.6% (TCD) of cases, residents reported there was no minimum declared number of exams required to achieve basic competency, while directors considered adequate for a resident's training a minimum number of 1–10 exams for each technique (e-Fig. 3). The assessment of ultrasound competency was described as mainly performed at the bedside by both directors (68.2%) and residents (58.2%; $p=0.373$, e-Fig. 4); residents reported a higher frequency of no assessment (37.7 vs. 9.1%; $p=0.06$) and a lower one of theoretical examinations (12.2 vs. 45.5%; $p<0.001$). Formal certification of theoretical and practical competency was performed in a minority of cases from the point of view of both residents and directors (7.7 and 9.1%; $p=0.685$, e-Fig. 4). Ultrasound machines were mostly available, mainly in the ICU (e-Table 1);

pre-hospital medicine resulted to be the less equipped setting according to both directors and residents.

Perceived importance and adequacy of training

The impact of ultrasound competency on clinical activity was mainly perceived by residents as extremely important (e-Fig. 5), for procedural safety (VA 96.3% and RA 89.6%) and for providing additional clinical information (LUS 89.3%, TTE 88.8%, TCD 72.7%, FAST 84.4%, DUS 69.9%—e-Fig. 6). The relevance of ultrasound competency in the global evaluation of the residents is shown in Fig. 2; residents tend to underestimate the relevance given by directors. The training was described by residents mainly as adequate or more than adequate for VA (62.2%) and RA (46.1%) and mainly as inadequate or very inadequate for all the other techniques (FAST 54.6%, TCD 50.3%, TTE 46.4%, DUS 45.2%, LUS 33.1%—e-Fig. 7). Accordingly, residents felt mostly confident or very confident in VA only (58.7%), while they felt uncomfortable or very uncomfortable in practicing all the other techniques (TCD 87.6%, DUS 80.6%, FAST 76.2%, TTE 75.5%, LUS 50.4%, RA 48.0%—e-Fig. 8). Directors mainly agreed or strongly agreed on the need of ultrasound training improvement in all the analysed fields (TTE



54.5%, FAST 50.0%, LUS 45.5%, TCD 40.9%, RA 40.9% DUS 36.4%—e-Fig. 9) except for VA (18.2%).

Limiting factors and potential improvement

Limiting factors are displayed in Table 2. From the residents' point of view, the most relevant limiting factor for all the analysed techniques was the lack of a standardized training program (VA 48.7%, LUS 49.9%, TTE 52.7%, FAST 52.5%, TCD: 45.5%, RA: 40.6%, DUS: 43.4%), followed by limited availability and skills from mentors. According to the directors' opinion, limited mentors' skills were the most relevant limiting factor for most of the techniques.

Discussion

In this survey on the current state of ultrasound training in Italian critical care, anaesthesia, and pain therapy residency schools we found that 1. ultrasound teaching in Italian residency school is mainly based on bedside teaching and classroom lessons, is mentored by consultant physicians, and is perceived as adequate for vascular access only; 2. there are significant discrepancies in residents' and directors' perception of many aspects of the training; 3. despite the high relevance of ultrasound competency from both residents and directors, a formal certification of theoretical and practical skills is rarely performed, which is perceived as the main limitation to ultrasound teaching by residents.

The strengths of the present survey are that this is the first prospective survey in Italy for ultrasound training in critical care, anaesthesia, and pain therapy residency schools. Secondly, it clearly focused on questions concerning a variety of aspects of the POCUS training. Finally, it provided opinions from directors and residents for comparison, an essential aspect to improve the education system.

A consensus of the European Society of Intensive Care Medicine recently defined the basic ultrasound knowledge required for all intensivists [34]: most of the ultrasound techniques investigated in this survey are now considered essential for physician in this field and the question on how to structure a shared ultrasound curriculum to effectively acquire and maintain ultrasound expertise is crucial.

Our results show that the most common training tools are bedside teaching and classroom lessons; this is consistent with literature describing them as the easiest and most well-established tools [24]. Recent studies suggested to implement the currently diffuse face-to-face lecture model with the adoption of flipped classroom [35–39], social media [40–43] and online learning [44–48]. Online modules were rarely adopted in Italian training programs, although appreciated by residents who

reported an extensive use of web-based tools. It has to be noted that the survey ended before the novel coronavirus 2019 pandemic, that pushed many universities to implement web-based training, hybrid web-based / in-person training and also mobile applications for informal group case-based discussions [49, 50]. Participation in research projects is also an opportunity for young physicians to work with experts in a field, to study a topic in depth and to receive dedicated training; however, this is reported as infrequent by residents. Simulation was infrequent in Italian residency schools, similar to what was previously reported in the United States [24], although it has been shown to enhance knowledge level, dexterity and confidence [51, 52]. Liberal practice should also be encouraged and structured since it is fundamental to improve technical skills and confidence [53].

Residents are mainly mentored by consultant physicians, similar to what has been previously reported in other countries [30, 54]; this implies a potentially ununiform training. POCUS is used and established in different ways and settings on the basis of each hospital's experience; especially when the most innovative techniques are being used and taught, the expertise is not homogeneous [23, 53, 55]. Such heterogeneity may lead to the development of a dysfunctional cycle where consultants who have insufficient expertise [30] are in charge of educating trainees who then perceive their education as inadequate [54]. Accordingly, mentors with limited skills are perceived as the main limitation by directors. Similar barriers to ultrasound training are perceived in other countries [23–25, 29, 30], in particular, the lack of trainers' expertise and available time and the need for a standardized curriculum. Other core elements have also been suggested to improve ultrasound training, such as structured image storage, documentation, and quality assurance [29].

Overall, the training is perceived as adequate by both residents and directors for VA only; this may be explained by the fact that this basic technique is widely spread among intensivists and anaesthesiologists and corresponds to a training target beginning in the first year of school for all residents. The most neglected technique is FAST, probably because it is mainly performed in extra-hospital scenarios or in the emergency department. In our data, its teaching is nevertheless considered important and could easily be implemented using healthy volunteers with a steep learning curve [56].

Many discrepancies emerged between the opinions of residents and directors. The relevance given to ultrasound competency is high for both residents and directors; however, the relevance given by directors is frequently underestimated by residents. Regarding teaching organization, directors report more classroom

Table 2 Limiting factors for ultrasound training

	Limited mentor's time-availability			Limited mentor's skills			Ultrasound machine availability			Limited resident's time-availability			Lack of a standardized training program			I don't know			No clear limitations		
	R	D	P value	R	D	P value	R	D	P value	R	D	P value	R	D	P value	R	D	P value	R	D	P value
VA	209 (38.2)	4 (18.2)	0.057	72 (26.0)	3 (13.6)	0.949	165 (30.2)	8 (36.4)	0.535	100 (18.3)	0 (0.0)	0.027	278 (50.8)	7 (31.8)	0.080	24 (4.4)	8 (36.4)				
LUS	191 (38.7)	8 (36.4)	0.823	147 (32.9)	10 (45.5)	0.119	108 (21.9)	5 (22.7)	0.927	80 (16.2)	0 (0.0)	0.040	285 (57.8)	7 (31.8)	0.016	78 (14.3)	3 (13.6)				
TTE	208 (43.4)	7 (31.8)	0.282	164 (34.2)	7 (31.8)	0.815	106 (22.1)	4 (18.2)	0.662	85 (17.7)	2 (9.1)	0.295	301 (62.8)	7 (31.8)	0.003	92 (16.8)	2 (9.1)				
FAST	159 (34.3)	6 (27.3)	0.498	142 (30.6)	8 (36.4)	0.568	73 (15.7)	6 (27.3)	0.152	67 (14.4)	1 (4.5)	0.191	300 (64.7)	9 (40.9)	0.024	107 (19.6)	4 (18.2)				
TCD	133 (31.7)	7 (31.8)	0.994	162 (38.7)	9 (40.9)	0.833	76 (18.1)	5 (22.7)	0.588	56 (13.4)	1 (4.5)	0.229	260 (62.1)	7 (31.8)	0.050	152 (27.8)	3 (13.6)				
RA	194 (37.5)	6 (27.3)	0.333	154 (29.7)	4 (18.2)	0.244	158 (30.5)	6 (27.3)	0.747	99 (19.1)	2 (9.1)	0.238	232 (44.8)	4 (18.2)	0.014	53 (9.7)	8 (36.4)				
DUS	139 (32.0)	6 (27.3)	0.640	164 (37.8)	9 (40.9)	0.621	75 (17.3)	4 (18.2)	0.812	57 (13.1)	0 (0.0)	0.040	247 (56.9)	5 (22.7)	0.035	137 (25.0)	5 (22.7)				

Data are displayed as values (percentage). In bold: statistically significant p values for comparison between residents and directors, for each technique and limiting factor

R Residents, D Directors, VA Vascular access, LUS Lung ultrasound, TTE Trans thoracic echocardiography, FAST Focused assessment with sonography in trauma, TCD Transcranial Doppler, RA Regional anaesthesia, DUS Diaphragm ultrasound

lessons, participation to research projects and supported extra-curricular ultrasound courses. The number of required exams to achieve basic competency for each technique is also higher from the directors' point of view, but not always in line with the literature [16–20]. This discrepancy may be due to difficulties faced by directors in keeping the level of didactic activity and in keeping resident evaluation as high as planned. In addition, a lack of clear communication between directors and residents may lead to the residents underestimating the teaching opportunities offered by the residency schools.

Directors also report a higher percentage of theoretical evaluation of ultrasound competency, probably also considering the assessment of ultrasound competency performed during the general annual residency final examination. Residents seem to prefer a more dedicated and planned training curriculum with a declared number of expected exams and a formal certification, *i.e.*, a shared ultrasound curriculum.

A formal certification is in fact recognized as lacking by both directors and residents, with both groups wishing to improve the quality of ultrasound teaching. The lack of a standardized teaching program is not new in ultrasound training, where national and international societies are trying to set standards for each technique and for a sharable curriculum for ultrasound in critical care [16, 21, 34, 57–60]. Some years ago, Galarza et al. [23] compared the state of critical care ultrasound training among European countries: only 5/42 countries had a national training program, and no agreement was found between these five. To investigate the state of ultrasound training in pulmonary critical care fellows in the United States, Brady et al. also sent a survey to program directors, who were then charged with enrolling their fellows [24]: results showed that most of the fellows received some type of formal training and were mainly self-trained at the bedside, while a minority used simulations or could be supervised by a mentor. Mosier et al. [30] described bedside ultrasound use and training among critical care training programs in the United States with a cross-sectional survey sent to program directors: the use and acknowledged usefulness of ultrasound techniques were very high, but directors recognized the need to improve ultrasound training that was mainly based on informal teaching with limited use of simulations, review sessions and dedicated mentors. Mizubuti et al. [25] analyzed 17 Canadian residency training programs for anesthesiologists: formal rotations resulted to be more frequent than what was reported by our survey; however, a well-defined minimum target of exams was set in only 4

training programs. Moreover, it must be noted that the questionnaire was sent to directors only.

To improve ultrasound teaching in anaesthesia and critical care residency schools, based on our findings and previous literature, we suggest: 1. to improve communication between directors and residents via mailing lists, websites and digital reminders to overcome part of the discrepancies between the two groups; 2. to implement those educational approaches that are now used in a limited manner (new technology for online learning, near-peer education, simulation); 3. to structure a standardized training program, with dedicated mentors, well-defined training goals and formal certification, all reported as major limitations by residents; 4. to build an educational network between schools based on ultrasound competency to overcome the lack of expertise in trainers, a major limitation reported by directors.

This survey presents many limitations. First, a lower-than-expected number of responses was obtained, thus the results may not perfectly reflect the state of ultrasound training in Italy; however, the absolute number of participants is high, and the residents' actual response rate is unknown, since we relied on individual program directors to forward our survey on to their respective residents. Nevertheless, we have a good homogeneity of responses per residency year and geographical distribution. Results were not adjusted as a function of the level of training of the residents; this limitation was mitigated by the possibility to answer "not yet encountered in my training" in each question. Second, the two populations we compared are necessarily very different in numbers of components. Finally, results were not normalized per school, being each composed by a highly variable number of residents, in order not to penalize those with a limited number of responders.

Conclusions

POCUS education is present in Italian anaesthesia and critical care residency schools, but it does not fulfil the expectations in modalities outside of vascular accesses; the analysis of significant discrepancies between the perspectives of residents and directors may lead to suggestions for improvement of the educational system. Further research is needed to properly plan formal training programs.

Abbreviations

DUS: Diaphragm ultrasound; FAST: Focused assessment for trauma; LUS: Lung ultrasound; POCUS: Point-of-care ultrasound; RA: Regional anaesthesia; TTE: Transthoracic echocardiography; TCD: Transcranial Doppler; VA: Vascular access.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12909-022-03708-w>.

Additional file 1: e-Figure 1. Bubble chart for the number of residents' answers in each school according to director answer. In most cases, residents and directors who answered to the survey belonged to the same school (green bubbles). In orange, a minority of schools represented by residents only. Residency schools are shown as progressive number to keep them anonymous.

Additional file 2: e-Figure 2. Mentors for ultrasound training as perceived by residents and directors.

Additional file 3: e-Figure 3. Number of exams required by the residency school according to residents and considered adequate for training by residency school directors. VA: vascular access; LUS: lung ultrasound; TTE: transthoracic echocardiography; FAST: focused assessment with sonography in trauma; TCD: transcranial Doppler; RA: regional anaesthesia; DUS: diaphragm ultrasound. The comparison excluded those answering: "I don't know", being expected among residents only.

Additional file 4: e-Figure 4. Assessment of ultrasound competencies during residency school as perceived by residents and directors.

Additional file 5: e-Figure 5. Impact of ultrasound competencies on future working activity by residents. VA: vascular access; LUS: lung ultrasound; TTE: transthoracic echocardiography; FAST: focused assessment with sonography in trauma; TCD: transcranial Doppler; RA: regional anaesthesia; DUS: diaphragm ultrasound.

Additional file 6: e-Figure 6. Expected additional value in clinical activity of ultrasound techniques in the residents' view. VA: vascular access; LUS: lung ultrasound; TTE: transthoracic echocardiography; FAST: focused assessment with sonography in trauma; TCD: transcranial Doppler; RA: regional anaesthesia; DUS: diaphragm ultrasound.

Additional file 7: e-Figure 7. Adequacy of ultrasound training as perceived by residents in the different ultrasound techniques. VA: vascular access; LUS: lung ultrasound; TTE: transthoracic echocardiography; FAST: focused assessment with sonography in trauma; TCD: transcranial Doppler; RA: regional anaesthesia; DUS: diaphragm ultrasound.

Additional file 8: e-Figure 8. Confidence in performing ultrasound examination and procedures as perceived by residents. VA: vascular access; LUS: lung ultrasound; TTE: transthoracic echocardiography; FAST: focused assessment with sonography in trauma; TCD: transcranial Doppler; RA: regional anaesthesia; DUS: diaphragm ultrasound.

Additional file 9: e-Figure 9. Need of improvement in ultrasound teaching in their own residency school as perceived by directors. VA: vascular access; LUS: lung ultrasound; TTE: transthoracic echocardiography; FAST: focused assessment with sonography in trauma; TCD: transcranial Doppler; RA: regional anaesthesia; DUS: diaphragm ultrasound.

Additional file 10: Appendix 1. Survey sent to directors.

Additional file 11: Appendix 2. Survey sent to residents.

Additional file 12: e-Table 1. Availability of ultrasound machines in different clinical contexts according to directors and residents.

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Authors' contributions

SM, FB, PP, FM conceived the work; SM, FB, RV, GS, FM performed acquisition, analysis, and interpretation of data; SM, FB, CR, FM have drafted the work; CAV, CR, EB, LV, FC, SMM and PP substantively revised it. All the authors approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The Ethical committee (Comitato Etico Pavia) of the Fondazione IRCCS Policlinico S. Matteo, Italy waived the need for ethics approval and consent to participate. The study was approved and supported by the College of Professors in Anaesthesiology and Critical Care (CPAR); all methods were carried out in accordance with relevant guidelines and regulations (declaration of Helsinki). And informed consent was obtained from all subjects according to national regulation.

Consent for publication

Not applicable.

Competing interests

SM received fees for lectures from GE Healthcare, outside the present work. FM received fees for lectures from GE Healthcare, Hamilton Medical, SEDPA SpA, outside the present work. A research agreement is active between University of Pavia and Hamilton Medical, outside the present work. FL contributed to the development of a new helmet and he is designated as inventor (European Patent number 3320941). He also received speaking fees from Fisher & Paykel, Draeger and Intersurgical. RV received an honorarium for a lecture from Intersurgical. The other authors report no conflicts of interests.

Author details

¹Anesthesia and Intensive Care 1, Fondazione IRCCS Policlinico S. Matteo, Pavia, Italy. ²Rianimazione I, Fondazione IRCCS Policlinico S. Matteo, DEA piano -1, Viale Golgi 19, 27100 Pavia, Italy. ³Anesthesia and Intensive Care, ASST-Pavia – Civil Hospital of Vigevano, Pavia, Italy. ⁴Department of Translational Medicine, Eastern Piedmont University, Novara, Italy. ⁵Anesthesia and Intensive Care, Ospedale Maggiore della Carità, Novara, Italy. ⁶Anesthesia and Intensive Care, IRCCS for Oncology and Neurosciences, San Martino Policlinico Hospital, Genoa, Italy. ⁷Department of Surgical Sciences and Integrated Diagnostics, University of Genoa, Genoa, Italy. ⁸Department of Clinical-Surgical, Diagnostic and Pediatric Sciences, Unit of Anesthesia and Intensive Care, University of Pavia, Pavia, Italy. ⁹Department of Morphology, Surgery and Experimental Medicine, University of Ferrara, Ferrara, Italy. ¹⁰Department of Anesthesia and Intensive Care, Parma University Hospital, Parma, Italy. ¹¹Department of Medical, Oral and Biotechnological Sciences, University of Chieti-Pescara, Chieti, Italy. ¹²Department of Anesthesiology, Critical Care Medicine and Emergency, SS. Annunziata Hospital, Chieti, Italy. ¹³Anesthesia and Intensive Care, Ente Ospedaliero Ospedali Galliera, Genoa, Italy. ¹⁴Department of Surgical, Medical and Molecular Pathology and Critical Care Medicine, University of Pisa, Pisa, Italy.

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References

- Finfer S, Vincent J-L. Critical Care—An All-Encompassing Specialty. *N Engl J Med*. 2013;7:369.
- Kolev N, Brase R, Swanevelde J, et al. The influence of transoesophageal echocardiography on intra-operative decision making. A European multicentre study. *Anaesthesia*. 1998;53(8):767–73.
- Lamperti M, Biasucci DG, Disma N, et al. European Society of Anaesthesiology guidelines on peri-operative use of ultrasound-guided for vascular access (PERSEUS vascular access). *Eur J Anaesthesiol*. 2020;37(5):344–76.
- Boselli E, Hopkins P, Lamperti M, et al. European Society of Anaesthesiology and Intensive Care Guidelines on peri-operative use of ultrasound for regional anaesthesia (PERSEUS regional anaesthesia). *Eur J Anaesthesiol*. 2021;38(3):219–50.
- Zieleskiewicz L, Muller L, Lakhal K, et al. Point-of-care ultrasound in intensive care units: assessment of 1073 procedures in a multicentric, prospective, observational study. *Intensive Care Med*. 2015;41(9):1638–47.
- Levitov A, Frankel HL, Blaivas M, et al. Guidelines for the appropriate use of bedside general and cardiac ultrasonography in the evaluation of critically ill patients - Part II: Cardiac ultrasonography. *Crit Care Med*. 2016;44(6):1206–27.
- Mojoli F, Bouhemad B, Mongodi S, Lichtenstein D. Lung ultrasound for critically ill patients. *Am J Respir Crit Care Med*. 2019;199(6):701–14.
- Tuinman PR, Jonkman AH, Dres M, et al. Respiratory muscle ultrasonography: methodology, basic and advanced principles and clinical applications in ICU and ED patients—a narrative review. *Intensive Care Med*. 2020;46:594–605.
- Bertuetti R, Gritti P, Pelosi P, Robba C. How to use cerebral ultrasound in the ICU. *Minerva Anesthesiol*. 2020;86(3):327–40.
- Zieleskiewicz L, Fresco R, Duclos G, et al. Integrating extended focused assessment with sonography for trauma (eFAST) in the initial assessment of severe trauma: Impact on the management of 756 patients. *Injury*. 2018;49(10):1774–80.
- Laursen CB, Sloth E, Lassen AT, et al. Point-of-care ultrasonography in patients admitted with respiratory symptoms: a single-blind, randomised controlled trial. *Lancet Respir Med*. 2014;2(8):638–46.
- Bobbia X, Zieleskiewicz L, Pradeilles C, et al. The clinical impact and prevalence of emergency point-of-care ultrasound: a prospective multicenter study. *Anaesthesia Crit Care Pain Med*. 2017;36(6):383–9.
- Broggi E, Bignami E, Sidoti A, et al. Could the use of bedside lung ultrasound reduce the number of chest x-rays in the intensive care unit? *Cardiovasc Ultrasound*. 2017;15(1):23.
- Mongodi S, Orlando A, Arisi E, et al. Lung ultrasound in patients with acute respiratory failure reduces conventional imaging and health care provider exposure to COVID-19. *Ultrasound Med Biol*. 2020;46(8):2090–3.
- Blanco P, Volpicelli G. Common pitfalls in point-of-care ultrasound: a practical guide for emergency and critical care physicians. *Crit Ultrasound J*. 2016;8(1):15.
- Robba C, Poole D, Citerio G, et al. Brain ultrasonography consensus on skill recommendations and competence levels within the critical care setting. *Neurocrit Care*. 2020;32(2):502–11.
- Arbelot C, Neto FLD, Gao Y, et al. Lung ultrasound in emergency and critically ill patients: number of supervised exams to reach basic competence. *Anesthesiology*. 2020;132(4):899–907.
- Rouby JJ, Arbelot C, Gao Y, et al. Training for lung ultrasound score measurement in critically ill patients. *Am J Respir Crit Care Med*. 2018;198(3):398–401.
- Neskovic AN, Skinner H, Price S, et al. Focus cardiac ultrasound core curriculum and core syllabus of the European Association of Cardiovascular Imaging. *Eur Heart J Cardiovasc Imaging*. 2018;19(5):475–81.
- Moureau N, Lamperti M, Kelly LJ, et al. Evidence-based consensus on the insertion of central venous access devices: Definition of minimal requirements for training. *Br J Anaesth*. 2013;110(3):347–56.
- Wong A, Galarza L, Forni L, et al. Recommendations for core critical care ultrasound competencies as a part of specialist training in multidisciplinary intensive care: a framework proposed by the European Society of Intensive Care Medicine (ESICM). *Crit Care*. 2020;24(1):393.
- Flower L, Dempsey M, White A, Sanfilippo F, Olusanya O, Madhivathanan PR. Training and accreditation pathways in critical care and perioperative echocardiography. *J Cardiothorac Vasc Anesth*. 2021;35(1):235–47.
- Galarza L, Wong A, Malbrain MLNG. The state of critical care ultrasound training in Europe: a survey of trainers and a comparison of available accreditation programmes. *Anaesthesiol Intensive Ther*. 2017;49(5):382–6.
- Brady AK, Spitzer CR, Kelm D, Brosnahan SB, Latifi M, Burkart KM. Pulmonary critical care fellows' use of and self-reported barriers to learning bedside ultrasound during training: results of a national survey. *Chest*. 2021;160(1):231–7.
- Mizubuti G, Allard R, Ho AMH, Cummings M, Tanzola RC. A survey of focused cardiac ultrasonography training in Canadian anesthesiology residency programs. *Can J Anesth*. 2017;64(4):441–2.
- Amini R, Adhikari S, Fiorello A. Ultrasound competency assessment in emergency medicine residency programs. *Acad Emerg Med*. 2014;21(7):799–801.
- Kim DJ, Theoret J, Liao MM, Kendall JL. Experience with emergency ultrasound training by Canadian emergency medicine residents. *West J Emerg Med*. 2014;15(3):306–11.
- Bahner DP, Goldman E, Way D, Royall NA, Liu YT. The state of ultrasound education in U.S. Medical schools: results of a national survey. *Acad Med*. 2014;89(12):1681–6.
- Conlon TW, Kantor DB, Su ER, et al. Diagnostic bedside ultrasound program development in pediatric critical care medicine: Results of a national survey. *Pediatr Crit Care Med*. 2018;19(11):E561–8.
- Mosier JM, Malo J, Stolz LA, et al. Critical care ultrasound training: a survey of US fellowship directors. *J Crit Care*. 2014;29(4):645–9.
- Rajamani A, Shetty K, Parmar J, et al. Longitudinal competence programs for basic point-of-care ultrasound in critical care. *Chest*. 2020;158(3):1079–89.
- Story DA, Tait AR. Survey research. *Anesthesiology*. 2019;130(2):192–202.
- Eysenbach G. Improving the quality of web surveys: The Checklist for Reporting Results of Internet E-Surveys (CHERRIES). *J Med Internet Res*. 2004;6(3):e34.
- Robba C, Wong A, Poole D, et al. Basic ultrasound head-to-toe skills for intensivists in the general and neuro intensive care unit population: consensus and expert recommendations of the European Society of Intensive Care Medicine. *Intensive Care Med*. 2021;1–21. <https://doi.org/10.1007/s00134-021-06486-z> In press.
- Martinelli SM, Isaak RS, Schell RM, Mitchell JD, McEvoy MD, Chen F. Learners and Luddites in the Twenty-first Century: Bringing Evidence-based Education to Anesthesiology. *Anesthesiology*. 2019;131(4):908–28.
- Martinelli SM, Chen F, McEvoy MD, Zvara DA, Schell RM. Utilization of the Flipped Classroom in Anesthesiology Graduate Medical Education: An Initial Survey of Faculty Beliefs and Practices About Active Learning. *J Educ Perioper Med*. 2018;20(1):E617.
- Martinelli SM, Chen F, DiLorenzo AN, et al. Results of a flipped classroom teaching approach in anesthesiology residents. *J Grad Med Educ*. 2017;9(4):485–90.
- Kraut AS, Omron R, Caretta-Weyer H, et al. The flipped classroom: a critical appraisal. *West J Emerg Med*. 2019;20(3):1–10.
- Hew KF, Lo CK. Flipped classroom improves student learning in health professions education: a meta-analysis. *BMC Med Educ*. 2018;18:38.
- Kwan C, Pusic M, Pecaric M, Weerdenburg K, Tessaro M, Boutis K. The variable journey in learning to interpret pediatric point-of-care ultrasound images: a multicenter prospective cohort study. *AEM Educ Train*. 2020;4:111–22.
- Li S, Lee-Chang A, Yagmour B, Khan R, Lieber J, Lee MM. Feasibility of a critical care ultrasound curriculum delivered through Facebook. *Cureus*. 2019;11(12):e6349.
- Amini R, Wang JB, Trueger NS, Hoyer R, Adhikari S. Use of social media in emergency ultrasound fellowship programs. *AEM Educ Train*. 2017;1:27–33.
- Hempel D, Sinnathurai S, Haunhorst S, et al. Influence of case-based e-learning on students' performance in point-of-care ultrasound courses: a randomized trial. *Eur J Emerg Med*. 2016;23(4):298–304.
- Smith A, Addison R, Rogers P, et al. Remote mentoring of point-of-care ultrasound skills to inexperienced operators using multiple telemedicine platforms is a cell phone good enough? *J Ultrasound Med*. 2018;37(11):2517–25.
- Ramsingh D, Van Gorkom C, Holsclaw M, et al. Use of a Smartphone-based augmented reality video conference app to remotely guide a point of care ultrasound examination. *Diagnostics*. 2019;9(4):159.

46. Wang S, Parsons M, Stone-Mclean J, et al. Augmented reality as a telemedicine platform for remote procedural training. *Sensors*. 2017;17(10):2294.
47. Robertson TE, Levine AR, Verceles AC, et al. Remote tele-mentored ultrasound for non-physician learners using FaceTime: a feasibility study in a low-income country. *J Crit Care*. 2017;40:145–8.
48. Burkholder TW, Bellows JW, King RA. Free Open Access Medical Education (FOAM) in Emergency Medicine: The Global Distribution of Users in 2016. *West J Emerg Med*. 2018;19(3):600–5.
49. Jackson R, Brotherston D, Jain A, Douflé G, Piquette D, Goffi A. Teaching ultrasound at the point of care in times of social distancing. *ATS Sch*. 2021;2(3):341–52.
50. Goldsmith AJ, Eke OF, Alhassan AI, Saud A, et al. Remodeling point-of-care ultrasound education in the era of COVID-19. *AEM Educ Train*. 2020;4(3):321–4.
51. Ramsingh D, Alexander B, Le K, Williams W, Canales C, Cannesson M. Comparison of the didactic lecture with the simulation/model approach for the teaching of a novel perioperative ultrasound curriculum to anesthesiology residents. *J Clin Anesth*. 2014;26(6):443–54.
52. Mendiratta-Lala M, Williams T, de Quadros N, Bonnett J, Mendiratta V. The use of a simulation center to improve resident proficiency in performing ultrasound-guided procedures. *Acad Radiol*. 2010;17(4):535–40.
53. Schott CK, Kode KR, Mader MJ. Teaching vs learning: Impact of deliberate practice and formative feedback on developing point of care ultrasound skills. *J Clin Ultrasound*. 2020;48(8):437–42.
54. Wenger J, Steinbach TC, Carlbom D, Farris RWD, Johnson NJ, Town J. Point of care ultrasound for all by all: a multidisciplinary survey across a large quaternary care medical system. *J Clin Ultrasound*. 2020;48(8):443–51.
55. Fusco P, Cofini V, Di Carlo S, et al. Ultrasonography and Italian anesthesiology: a national cross-sectional study. *J Ultrasound*. 2019;22(1):77–83.
56. Juo Y-Y, Quach C, Hiatt J, Hines OJ, Tillou A, Burruss S. Comparative Analysis of Simulated versus Live Patient-Based FAST(Focused Assessment With Sonography for Trauma) Training. *J Surg Ed*. 2017;74:1012–8.
57. Rajamani A, Smith L, Gunawan S, et al. Methodological quality of guidelines for training or competence processes for basic point of care echocardiography in critical care – A systematic review of the literature. *Chest*. 2021;160(2):616–23.
58. Singh Y, Tissot C, Fraga MV, et al. International evidence-based guidelines on Point of Care Ultrasound (POCUS) for critically ill neonates and children issued by the POCUS Working Group of the European Society of Paediatric and Neonatal Intensive Care (ESPNIC). *Crit Care*. 2020;24(1):65.
59. Kirkpatrick JN, Grimm R, Johri AM, et al. Recommendations for Echocardiography Laboratories Participating in Cardiac Point of Care Cardiac Ultrasound (POCUS) and Critical Care Echocardiography Training: Report from the American Society of Echocardiography. *J Am Soc Echocardiogr*. 2020;33(4):409–422.e4.
60. Calamai I, Greco M, Bertolini G, et al. Current adoption of lung ultrasound in Intensive Care Units: an Italian multi-center survey. *Minerva Anestesiol*. 2017;83(7):720–7.

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