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Assessment of knowledge on ultrasound physical principles and its application for image acquisition and optimization among emergency medicine trainees in Sri Lanka

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ABSTRACT

Introduction: The objective of the study was to assess the knowledge on physical principles of ultrasound and its application for image acquisition and optimisation among emergency medicine trainees in Sri Lanka.

Methods: A self-administered questionnaire consisting of 5 multiple choice questions and 10 single best response questions on ultrasound physical principles and their application in image acquisition and optimisation was distributed among 62 Pre-MD emergency medicine trainees. Knowledge scores were analysed with regards to prior experience and training in Point of Care Ultrasound (PoCUS).

Results: Fifty out of 65 trainees participated in the study giving a response rate of 76.9%. All registrars used PoCUS in their day-to-day practice and utilized one or more applications. The predominantly utilized application was trauma scans (n=47, 94%), followed by cardiac (n=44, 88%) and procedural guidance (n=44, 88%). The majority of the registrars (n=33, 66%) obtained a score above 50% for physics, whereas for image acquisition and optimisation, a score above 50% was obtained by 21 registrars (42%). There was no association between knowledge and completion of a PoCUS course (physical principles p=0.937, image acquisition and optimisation p=0.471) or experience in PoCUS (physical principles p=0.253, image acquisition and optimisation p = 0.648).

Conclusion and recommendations: In general, results of this study do not bode well on ongoing practice of PoCUS in Sri Lanka and indicates that the current PoCUS training is in urgent need of change and revision, with emphasis on the practical application.

Keywords: *Curriculum development, Emergency medicine, Imaging acquisition, Image optimisation, PoCUS training, Ultrasound physical principles.*

Introduction

Ultrasound is an affordable, portable, fast and safe method of assessing patients at the bedside (1-3). Due to these characteristics, it has evolved to become a fast-growing modality of imaging, making it an indispensable and valuable tool in diagnostic as well as therapeutic aspects of medicine (1). The maximum utility of ultrasound as a diagnostic tool, rests on understanding and manipulation of multiple physical principles (3).

Such knowledge enables the sonographer to optimise and interpret images, which in turn will improve safety, diagnostic accuracy as well as success of procedures (2, 4). The ability to acquire good quality images depends on knowledge on several key physical principles including physics of ultrasound waves, transducers, knobology, resolution, modes and artefacts (2,4). Inclusion of modules on ultrasound physics in ultrasound training curricula reflects and reinforces the importance of ultrasound physics in practice (4). The American Institute of Ultrasound Medicine (AIUM) thus include the following broad areas in their curriculum of fundamentals of ultrasound physics and instrumentation; basic physics of ultrasound, instrumentation, transducers, knobology and image optimisation, modes, artefacts and safety (4).

To date, no studies have provided concrete evidence that diagnostic ultrasound has deleterious effects on human tissues (1). However, practitioners of ultrasound are guided by the ALARA (As Low As Reasonably Achievable) principle (1, 5). The ALARA principle refers to the use of the lowest possible power setting necessary to generate the image (1). Potential bioeffects need to be considered particularly when scanning the foetus and the eye (1). Unfortunately, teaching of such vital aspects as bioharm and hygiene receives far less attention in short-duration Point of Care Ultrasound (PoCUS) courses than in formal long-duration ultrasound courses like diplomas.

It has been long identified by many emergency medicine colleges including the American College of Emergency Physicians (ACEP), the Royal College of Emergency Medicine (RCEM), and the Australasian College for Emergency Medicine (ACEM), that accreditation and mandatory training in ultrasound is a necessary component of emergency medicine fellowship programmes (6-9).

In Sri Lanka, the Emergency Medicine prospectus for the year 2021, lists participation at an accredited ultrasound workshop as a mandatory requirement during the training period, to be preferably completed during the first year of training. In addition, Focused Assessment using Sonography in Trauma (FAST), assessment of peritoneal cavity, pleural cavity, pericardial space, assessment of the abdominal aorta and inferior vena cava, vascular access, echocardiography in life support and lung ultrasound are outlined in the section on basic clinical skills (10). Despite the identification of the importance of acquisition of ultrasound skills, there is no formal programme that provides training and accreditation in ultrasound for emergency medicine trainees in Sri Lanka.

There currently are no published data assessing knowledge on fundamental ultrasound physical principles and how such knowledge is applied to optimise images among Sri Lankan emergency medicine trainees. Therefore, the information gathered through this study will yield insight into the training needs of trainees and further education opportunities.

Methods

This descriptive observational study was conducted during a two- month period from 10th July to 10th September 2023 with the participation of emergency medicine trainees attached to the Postgraduate Institute of Medicine, University of Colombo, Sri Lanka. The study population included Pre-MD emergency medicine trainees with at least 3 months of training (n= 65). Post-MD emergency medicine trainees, Pre-MD emergency medicine trainees on leave during the study period and Pre-MD emergency medicine trainees who have not completed at least three months of training were excluded from this study. The entire study population was taken in to the study without further sampling.

A self-administered structured questionnaire was utilized for data collection. It consisted of the following components: demographic information, factors associated with knowledge, knowledge on ultrasound physical principles and application of ultrasound physical principles for image acquisition and optimisation .

The questionnaire was designed based on reviewed manuals on emergency medicine ultrasound by the principal investigator in consultation with the supervisor, a consultant emergency physician with accreditation in PoCUS. The questionnaire was in English, as all participants had received their formal medical training in English medium.

The questionnaire consisted of 15 questions of the following types: 5 multiple choice questions and 10 single best response questions.

The decision whether a response to a given question was correct or not was made based on the reviewed manuals on emergency medicine ultrasonography used in development of the questionnaire. Each correct response carried one mark whereas no negative marks were carried forward for incorrect responses. The self-administered questionnaire was distributed via email to all eligible participants.

The details of the study were conveyed to all participants by means of an information sheet and informed written consent was obtained from each participant prior to data collection. All information collected through the study will be kept confidential. Participation in the study was entirely voluntary and the participants were not under any obligation to participate in the study. The participants also had the right to leave the study if they so wished, even following enrolment.

All data collected will be stored in a password protected computer for a period of 5 years from the date of publication. During this period, the safety, security, and confidentiality of all data will be ensured. At the completion of 5 years from the date of publication, all data will be permanently deleted from the system. Ethical clearance for the study was obtained from the Ethics Review Committee of the Postgraduate Institute of Medicine, Sri Lanka.

Descriptive statistical tests were utilized to analyse the data using *Statistical Package for the Social Sciences* (*SPSS*) Software.

Results

A total of 50 emergency medicine registrars participated in this study out of a total of 62, giving a response rate of 76.9%. Their PoCUS training and experience-related characteristics are given in Table 1.

Most of the registrars were in their third year of training (n=21/50, 42%) and did not have pre-MD experience in PoCUS (n=31/50, 62%). Out of the 19 participants who has had pre-MD experience in PoCUS, the majority had worked in emergency departments (n=8/19, 36.4%) prior to commencement of emergency medicine training. Most of the trainees had 2 or more years of experience in PoCUS (n=28/50, 56%). Most of the registrars had participated in a PoCUS course (n=40/50, 80%), out of which the majority had attended EM-PoCUS course (n=30/40, 75%). None of the trainees were accredited in PoCUS. All registrars used PoCUS in their day-to-day practice and utilized one or more applications. The predominantly utilized application was trauma scans (n=47, 94%), followed by cardiac (n=44, 88%) and procedural guidance (n=44, 88%).

Tables 2 to 4 provide a description of the knowledge of registrars on physical principles of ultrasound and image acquisition and optimisation.

Table 5 and Figure 1 describe the association between knowledge and PoCUS experience in years.

Table 6 and Figure 2 describe the association between knowledge and completion of a PoCUS course.

Table 1: Distribution of PoCUS training, and experience related characteristics of emergency medicine registrars in Sri Lanka

Demographic characteristics		**Number**	**(%)**
Year of Emergency Medicine Training	1	18	(36)
	2	11	(22)
	3	21	(42)
Pre-MD Experience in PoCUS	Yes	19	(38)
	No	31	(62)
Pre-MD Experience in PoCUS by type of Units worked in	Emergency Department	8	(36.4)
	Anaesthesia /Critical Care	7	(31.8)
	Medicine	3	(13.7)
	Obstetrics/Gynaecology	2	(9.1)
	Radiology	1	(4.5)
	Surgery	1	(4.5)
PoCUS Experience in Years	Less than 1 year	10	(20)
	1 to 2 years	10	(20)
	2 or more years	28	(56)
	None	2	(4)
Completion of a PoCUS Course	Yes	40	(80)
	No	10	(20)
PoCUS Course Completed	EM PoCUS	30	(75.0)
	WINFOCUS	5	(12.5)
	Emergency Sonography in trauma	1	(2.5)
	EM PoCUS and other courses	4	(10.0)
Accreditation in PoCUS	Yes	0	(0)
	No	50	(100)
Utility of PoCUS in Day-to-day Practice	Trauma	47	(94)
	Procedural guidance	44	(88)
	Cardiac	44	(88)
	Thoracic	41	(82)
	Deep Vein Thrombosis (DVT)	38	(76)
	Abdominal Aortic Aneurysm (AAA)	33	(66)
	Early Pregnancy	25	(50)
	Renal tract	24	(48)
	Hepatobiliary	20	(40)
	Musculoskeletal (MSK) & Soft tissue	16	(32)
	Ocular	11	(22)
	Bowel	7	(14)

Table 2: Distribution of correct responses for the Single Best Responses for the questions on ultrasound physical principles in ultrasound and image acquisition and optimisation

Physical principle	Number correct	Percentage
Modes (Q4)	31	62
Safety in First trimester scanning (Q8)	17	34
Knobology (Q1)	16	32
Artefacts in lung ultrasound (Q6)	16	32
Transducers (Q2)	15	30
Artefacts (Q5)	14	28
Resolution (Q3)	10	20
Thermal index for First trimester scans (Q9)	8	16
Image optimisation during ocular scans (Q15)	8	16
Optimisation of colour doppler (Q14)	6	12

Table 3: Distribution of correct responses for the Multiple-Choice Questions on ultrasound physical principles and image acquisition and optimisation

Topic	Number and Percentage of correct responses (Out of 250*)
Harmful effects (Q7)	180 (72%)
Patient manoeuvres (Q10)	162 (64.8%)
Image optimisation (Q11)	128 (51.2%)
Needle visualization (Q12)	112 (44.8%)
Safety (Q13)	108 (43.2%)

**The denominator of 250 was derived from 50 persons obtaining all five responses correct.*

Table 4: Distribution by level of knowledge

Level of knowledge	Below 50% n (%)	Above 50% n (%)
Ultrasound physical principles	17 (34%)	33 (66%)
Image acquisition and optimisation	29 (58%)	21 (42%)
Total score per individual	45 (90%)	5 (10%)

Table 5: Association between Knowledge and PoCUS experience in years

Knowledge category	**PoCUS Experience in years**		**Mean difference**	**95% Confidence Interval of the difference***		***p* value**
	Less than 2 years n=22	**2 years or more n= 28**		**Lower**	**Upper**	
Ultrasound physical principles Mean score	5.82	6.39	0.57	-0.424	1.574	0.253
Image acquisition and optimisation Mean score	10.23	10.68	0.45	-1.452	2.355	0.638

**Confidence intervals that cross zero indicate a non-significant p-value*

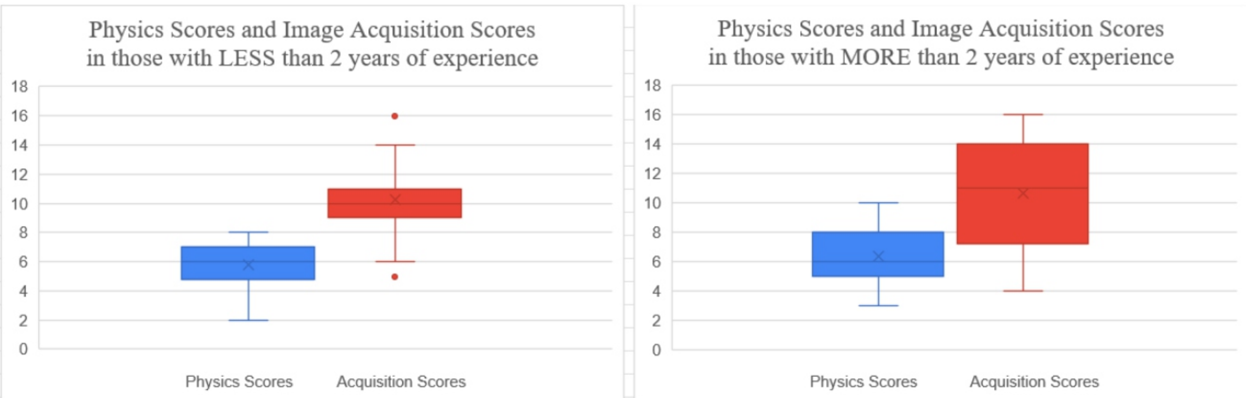

Figure 1: Association between knowledge and PoCUS experience in years*

**This plot demonstrates the spread of scores. The shaded box represents the interquartile range, the cross represents the median, whiskers represent the outer quartiles, and the dots are outliers. The maximum possible physics score is 13, and the maximum acquisition/optimisation score is 22.*

Table 6: Association between Knowledge and Completion of a PoCUS course

Knowledge category	Completion of a PoCUS course Mean		Mean difference	95% Confidence interval of the difference*		*p* value
	Yes n= 40	No n= 10		Lower	Upper	
Ultrasound physical principles	6.15	6.10	0.05	-1.207	1.307	0.937
Image acquisition and optimisation	10.65	9.80	0.85	-1.505	3.205	0.471

**Confidence intervals that cross zero indicate non-significant p-value*

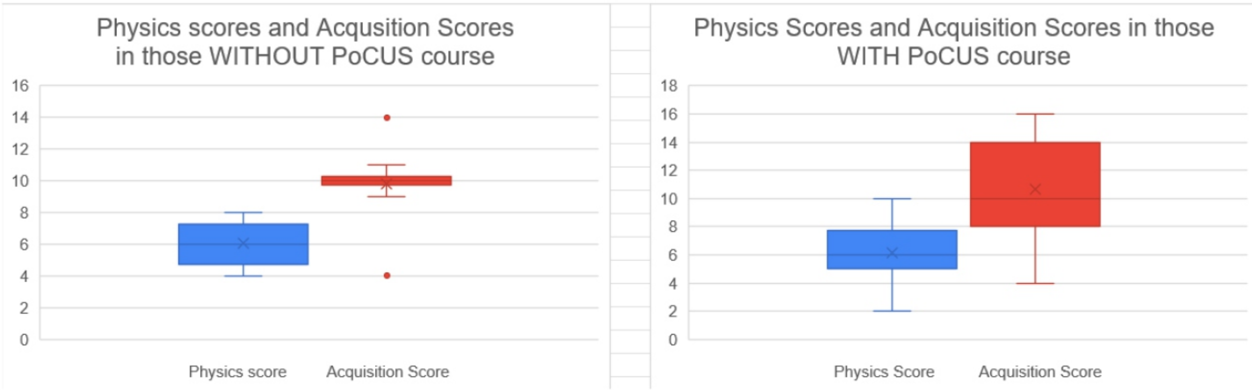

Figure 2: Association between knowledge and completion of a PoCUS Course*

**This plot demonstrates the spread of scores. The shaded box represents the interquartile range, the cross represents the median, whiskers represent the outer quartile and the dots are outliers. The maximum possible physics score is 13, and the maximum acquisition/optimisation score is 22.*

Out of a perfect score of 35, 13 questions were on physical principles and the remaining 22 questions tested acquisition and optimisation principles.

Discussion

The value of PoCUS in clinical practice relies upon acquisition of good images and the correct interpretation of the images obtained. As with any skill, PoCUS skills also improve with proper knowledge combined with practice. Thus the completion of a PoCUS course alone will not result in good PoCUS skills.

When comparing the overall scores obtained for the two components, most of the candidates were successful in obtaining above 50% for physics (66%), whereas the numbers were lower (42%) for image acquisition and optimisation .

In our study, we did not see any statistically significant difference between the mean scores obtained by those who had completed a PoCUS course and those who had not. We also did not see any significant difference in scores between the two groups based on experience in PoCUS. Another key observation in the group with over 2 years of experience was the greater spread in acquisition skills, implying that some may have got better while some may have got worse with time. It also implies inconsistencies in ongoing learning. This draws attention to the need of having follow up acquisition workshops to revise key components in image acquisition and optimisation .

Although the questions on physics were better answered than those on image acquisition and optimisation. Neither experience nor completion of a PoCUS course made any significant differences to the scores. Although most participants obtained over 50% for physics, when comparing the scores obtained by those who had attended a PoCUS course and those who had not, there was no significant difference. This points towards the possibility of the physics component of the course not being that well understood though majority had scored well for the theory component of physics.On the other hand, both experience and completion of a PoCUS course appear to have widened the spread of image acquisition and optimisation scores. This implies that some trainees did learn by experience and some trainees did learn from completion of a PoCUS course. However, the results also indicate that an equal number suffered skill decay. Our data, as depicted by the box and whisker plot shows that even though the average (or median) stayed the same, people did change because some improved while some got worse. However, since our sample size is small further study is required to qualify this statement.

The EM PoCUS course which is attended by most trainees is spread out across three days and covers extended Focused Assessment using Sonography in Trauma (eFAST), lung, DVT, hepatobiliary, cardiac, abdominal aortic aneurysm, renal, early pregnancy, Rapid Ultrasound for Shock and Hypotension (RUSH) protocol, and ultrasound guided procedures. Each skills station runs for approximately 1 to 2 hours, with 4 candidates per station. Thus, allowing significant hands-on time for each trainee, which is between 2 to 2.5 hours of scanning time per participant per day. However, this course covers 10 core topics in a span of 3 days. It might be beneficial to focus on fewer topics which will allow the candidates to get the most out of the course. Topics such as DVT, renal and hepatobiliary ultrasound can be covered in separate courses. Courses carried out the Australian Institute of Ultrasound, focus on fewer core topics thus allowing the candidate more hands-on time per module (15). The EM PoCUS course also offers pre course reading material and videos. It also assesses the candidates by way of pre-course and post course assessment tests. Other PoCUS courses conducted in Sri Lanka have a duration of 1 to 2 days, covering a wide range of PoCUS applications and less hands-on time. These courses do not offer pre-course preparatory material such as reading material or videos, and do not conduct a pre-test or post-test.

The German psychologist, Hermann Ebbinhaus, whose forgetting curve demonstrates how more than half of the memory is lost within the first hour of learning and continues to decline over the next few hours to days. However, Ebbinhaus also discovered that it is possible to prevent such drastic losses in memory by repetition of key facts and reviews at spaced intervals. Spaced repetition learning can be carried out in many forms. Revisiting key points at the end of the session, refresher courses to micro-learning and learning games on mobile devices (11,13,14).

There is also a significant dependence of retention and reproduction upon the intensity of attention and interest of an individual (11). Therefore, it is necessary to deliver lectures in a more engaging manner. Another successful method is the use of micro lessons on mobile applications to enhance knowledge retention and reproduction. Micro lessons involve breaking up of complex lengthy lessons into smaller lessons usually lasting from one to 10 minutes. With the utilization of micro lessons on mobile devices it also allows the user to learn at their own pace. In addition, utilization of different forms of media will aid in captivating the attention of the learner, thus further improving the rates of retention (12).

Limitations

The limitations of this study are the small sample size, the response rate of 76.9%, and the brevity of the questionnaire as a longer questionnaire would have resulted in a lower response rate. Secondly the PoCUS courses may not have been of equivalent efficacy and are not easily comparable post hoc.

Conclusion and Recommendations

The majority of the registrars had satisfactory knowledge on physics, whereas only a large minority of the registrars scored above average for image acquisition and optimisation. There was no statistically significant association between knowledge and completion of a PoCUS course. There was also no significant association between knowledge and PoCUS experience.

In general, this study does not bode well for ongoing practice of PoCUS in Sri Lanka and suggests that the current PoCUS training is in urgent need of revision, with emphasis on the practical application of the physics principles and safety. A simplified format where the key physical principles can be delivered to the participants while highlighting the application of physics to practicalities of scanning might improve the participants understanding and retention of knowledge.

Providing pre-course learning material will give the necessary foundation knowledge allowing the candidates to acquire the optimum benefit of the course. It will also give them the opportunity to voice any queries that they have from the trainers. In addition, this will allow more time for hands-on sessions, by reducing the number of formal lectures during the course.

It would also be beneficial to have spaced repetition courses focusing on a single PoCUS application, *e.g.* 1-day lung PoCUS, 1-day cardiac PoCUS. This will allow trainees to utilize the knowledge, and skills acquired effectively in their day-to-day practice. Such courses may prevent rapid degradation of knowledge and skills over time.

Introduction of in-service assessments and regular PoCUS teaching would be beneficial as the trainee would have the opportunity of being directly observed on the floor. This can be achieved by adopting a training set up similar to that of the Australian emergency medicine registrars, by providing the opportunity for trainees to opt to take a special skills term in PoCUS, where the trainee will be directly under the supervision of a PoCUS-accredited instructor. This will enable the trainee to perform many scans in a short period of time, thus consolidating their knowledge through experience. Regular ultrasound meetings where the trainees can present cases of their saved ultrasound images and clips can be a useful learning exercise.

Teaching should be targeted not only towards delivery of knowledge and acquisition of skills but also towards blunting the forgetting curve as much as possible.

Lectures should be simplified and designed to be more engaging. Micro lessons on mobile devices will allow revision of knowledge at the trainee's own pace. Courses should be structured utilizing a multi-modality approach. Spaced repetition (refresher) courses will help gain lost knowledge. Further research is recommended with specific pre and post new-course questionnaires. Providing trainees with the opportunity of opting for an ultrasound term under the supervision of a PoCUS accredited trainer, regular teaching in the form of in-service assessments and ultrasound meetings will further improve the rates of retention while improving skills of the trainees.

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