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Learning curves in abdominal ultrasound in medical students

Tudor Moga[1], Greta Dancu[1], Radu Cotrau[1], Renata Bende[1], Alina Popescu[1], Mirela Danila[1], Ariana Plopeanu[1], Teofana Bizerea-Moga[2], Ana Bona[3], Sporea Ioan[1], Roxana Sirli[1]

[1]Center for Advanced Research in Gastroenterology and Hepatology, Department of Internal Medicine II, Division of Gastroenterology and Hepatology, [2]1st Pediatric Department, [3]Department of Intensive Care Unit, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

Abstract

Aims: Ultrasound (US) is an essential diagnostic and educational tool in medical practice, and its effective implementation into medical curricula is critical. This study aimed to compare the efficacy of two disparate educational approaches—an optional semester course and a specifically curated intensive workshop—on the learning curve of medical students in abdominal ultrasonography. **Material and methods**: Engaging fourth and fifth-year medical students, this study, incorporated both theoretical and practical elements of US, providing participants with hands-on experience and evaluative assessments pre- and post-training. Students were segregated into two groups: one experienced a 14-hour optional semester course and the other a 6-hour intensive workshop, both yielding distinct teaching methodologies yet aspiring for synonymous educational outcomes. **Results**: Involving a total of 93 participants, findings elucidated that regardless of the educational method employed, post-training identification of US structures exhibited a significant enhancement compared to pre-training. Interestingly, no substantial disparities were discerned between the two educational approaches nor gender-based differences in learning outcomes. **Conclusions**: This investigation provides pivotal insights into the versatile utility of different educational strategies in abdominal US training for medical students, affirming that varied pedagogical methods can achieve comparable augmentations in student proficiency. Further research is paramount to ascertain the optimal integration of US education into medical curricula, considering aspects such as duration, depth, and mode of delivery.

Keywords: medical education; abdominal ultrasonography; learning curve; medical students

Introduction

Ultrasound (US) is currently considered essential in complementing clinical examination [1]. However, its significant disadvantage is its operator dependence. This makes the need crucial for medical personnel to be trained in performing comprehensive and accurate assessments, even from the early stages of their education.

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Corresponding author: Greta Dancu
Center for Advanced Research
in Gastroenterology and Hepatology,
Department of Internal Medicine II,
Division of Gastroenterology and Hepatology,
"Victor Babes" University of Medicine and
Pharmacy, 2 Eftimie Murgu Sq,
300041 Timisoara, Romania
E-mail: gretadancu@gmail.com

Abdominal US is a practical exploration method that does not demand significant effort to master it, which is why the students are increasingly interested in acquiring the necessary skills [2]. Learning the basic concepts of US can be more costly and time-consuming later, especially when students become residents. This learning curve can be shortened if the training begins during undergraduate studies.

Although there are many papers that analyse the learning curve of US in various settings; for example, in emergency medicine, gynecological practice, or intensive care units, there is no standardized method for education in abdominal US. American guidelines recommend a minimum of 150 (or 25–50 for each core) US examinations for general competence [3]. Some papers suggest fewer examinations might be sufficient [4], while others argue that not just the number of examinations, but also image quality - influenced by patient characteristics - is an important factor [5]. This inconsistency in

the literature suggests that a universal learning method, guiding students on how to use and perform a standard abdominal US examination from A to Z, has not yet been established. As a result, we chose this topic to compare students from different years of study having a distinct study method: either an optional semester or a specially designed intensive workshop for ABC-type US. The aim of the study was to analyse, based on the two learning approaches, the learning curve in abdominal US for students and to determine which method would be the most beneficial.

Materials and methods

The study was conducted from 2018 to 2019 and engaged the fourth and fifth-year medical students enrolled in our University. The students who have attended the elective abdominal US ultrasound courses within the University curricula [6] and the students joining the workshops focusing on ABC in Abdominal Ultrasonography were enrolled in the study. Anonymously conducted, the assessment protocol entailed pre- and post-training evaluations. The evaluation consisted of a theoretical assessment, in the form of a multiple-choice test, and a practical evaluation via an US examination).

Description

Depending on the US teaching method, the students were divided into two groups. The first group comprised the 4th year students enrolled in an optional US course at the university. Over the course, they received approximately 14 hours of classroom instruction and an equal amount of hands-on training, cycling through three US stations. The second group was made up of 5th year students enrolled in an US workshop organized by dedicated students and coordinated by medical doctors skilled in abdominal US (with more than 5 years experience in abdominal US). Within the workshop, students were provided 3 hours of intensive theoretical instruction followed by 3 hours of full-time assisted hands-on training.

For both groups, hands-on sessions and the final practical evaluations were conducted on three US stations in the Gastroenterology Department using Mindray portable US devices (DP10 with a 3.5 MHz convex probe) [7]. During both training and evaluation, students practiced the US examination on each other, under the direct guidance of the coordinators.

Both groups underwent practical evaluations before and after training, wherein students were required to identify the structures mentioned in Table I, using the corresponding probe location. Students also completed a multiple-choice test comprising 20 questions about the sections used to identify various anatomical structures, their US appearance, and the advantages and disadvantages of US. The evaluation was performed both before and after the training, using the same method.

Statistical analysis

Statistical analysis was carried out using MedCalc Version 19.4 (MedCalc Software Corp., Brunswick, ME, USA) and Microsoft Office Excel 2019 (Microsoft for Windows). The Kolmogorov–Smirnov test determined the distribution of numerical variables. As a result, continuous variables with a normal distribution were presented as mean and standard deviations (SD). Those with a non-normal distribution were depicted as median with their associated interquartile ranges (IQRs). Meanwhile, categorical variables were expressed as counts (percent-

Table I. Anatomical structures to be identified and the suggested probe location

Anatomical Structure	Right Upper Quadrant	Left Upper Quadrant	Suprapubic Region	Sub-xiphoid Region
Hepatic Structure	X			
Left Hepatic Lobe	X	X		
Caudate Lobe, Segment I	X			
Hepatic Hilum	X			
Suprahepatic Veins	X			
Portal Bifurcation	X			
Gallbladder	X			
Morrison Space	X			
Pancreas & Spleno-Portal Ax	X	X		
Aorta	X	X		X
Inferior Vena Cava	X			X
Left Kidney		X		
Right Kidney	X			
Spleen		X		
Bladder & Douglas Space			X	
Uterus/Prostate			X	

ages). Comparisons between categorical variables across groups were made using Pearson's χ^2-test.

Ethical Approval

Because this was an observational study, performed with a retrospective design using a database and medical records, informed consent was waived. However, all participants give their oral content prior to the study.

Results

The study included 93 subjects: 26 fourth-year students who enrolled in the optional university course and 67 fifth-year students who participated in a three-day workshop. The total number of US structures identified by students during an abdominal US, both before and after the course, was compared. Regardless of the method of course organization (optional course or workshop), the total number of US structures recognized after the course was significantly higher than the initial examination (14 [10-16] vs. 5 [1-10], p<0.0001 for the optional course; 12 [7-15] vs. 7 [3-12], p<0.0001 for the workshop) (fig 1). Furthermore, no differences were observed between the total number of structures identified by students after the optional course and after the workshop, respectively (14 [10-16] vs. 12 [7-15], p<0.0001) (fig 2). Upon closer analysis, there were no differences in the number of US structures identified at the end of the two course formats based on gender (p<0.0001) (fig 3). The proportion of students who correctly identified the main US structures at the start, and at the end of the course/workshop is summarized in Table II.

Discussion

US is considered a first-line imaging modality in many clinical settings [8], given it is non-invasive, repetitive, and non-irradiating. The effectiveness of this tool largely hinges on the operator's experience, and its significance varies depending on the region. Given these factors, it appears wise to consider its incorporation into the students' medical curriculum. In Europe, perhaps the best example is the German system, where experiments analysing the role of US in education were conducted 30 years ago [9]. Outside Europe, the University of South Carolina School of Medicine reported their results about implementing US in their curricula. Incorporating US training early in the curriculum, often aligning it with anatomy and physiology courses, not only aids in the understanding of the subject matter but also allows students to familiarize themselves with the US technology [10].

All reports suggest that US is a valuable tool in helping students learn anatomy, physiology, and pathophysiology. In contrast to medical schools that have a long tradition regarding the integration of US in medical education, there are numerous universities, like ours, with a shorter history.

Even though in recent years a number of publications on this topic have emerged, there is a lack of standardization regarding the integration of US in medical curricula, not only concerning the timing of implementation but also the structure of the courses. In the last ten years, the World Federation for Ultrasound in Medicine and Biology (WFUMB) and its federation of Societies have cre-

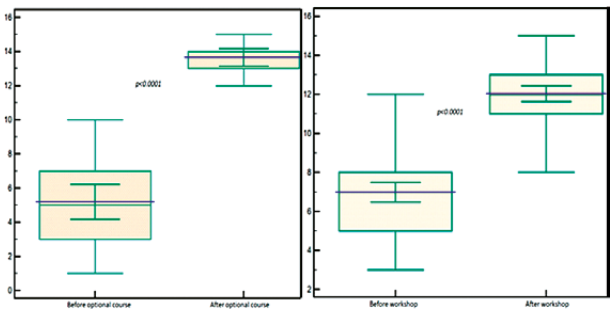

Fig 1. The total number of ultrasound structures recognized before and after the optional course and workshop

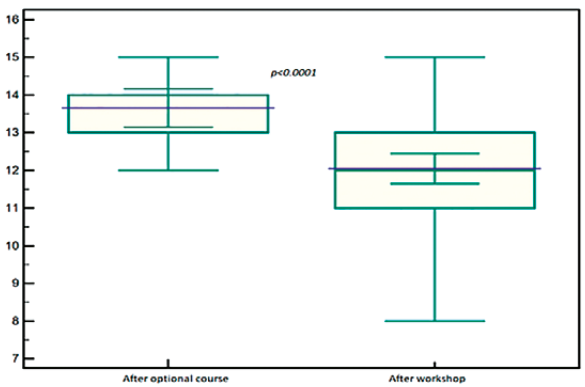

Fig 2. Comparison between the total number of ultrasound structures recognized after the optional course and workshop

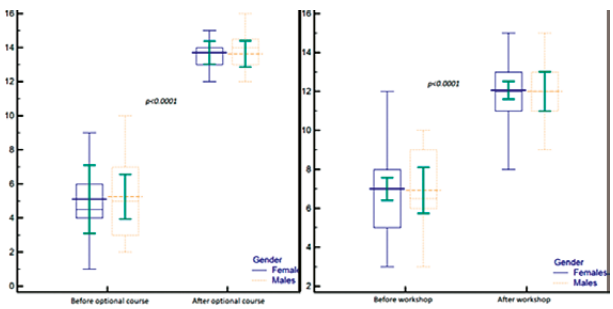

Fig 3. Comparison between genders regarding the total number of ultrasound structures recognized after the optional course and workshop, respectively

Table II. The proportion of students who correctly identified the main ultrasound structures.

Parameter	Optional course n=26			Workshop n=67		
	Before	After	p value	Before	After	p value
Hepatic structure	57.7 (15)	100 (26)	0.0007	58.2 (39)	100 (67)	<0.0001
Left liver Lobe	50 (13)	100 (26)	0.0001	53.7 (36)	100 (67)	<0.0001
Caudate lobe	3.8 (1)	69.2 (18)	<0.0001	37.3 (25)	59.7 (40)	0.0181
Hepatic hilum	11.5 (3)	53.8 (14)	0.0031	34.3 (23)	70.7 (34)	0.0001
Suprahepatic veins	26.9 (7)	76.9 (20)	0.0009	46.3 (31)	68.6 (46)	0.0149
Portal vein bifurcation	30.8(8)	88.5 (23)	0.0001	44.8 (30)	43.3 (29)	0.9993
Gallbladder	23 (6)	96.1 (25)	<0.0001	41.8 (28)	70.1 (47)	0.0018
Morison's pouch	19.2 (5)	84.6 (22)	<0.0001	46.3 (31)	73.1 (49)	0.0028
Pancreas and splenoportal axis	19.2 (5)	69.2 (18)	0.0008	13.4 (9)	43.3 (29)	0.0003
Aorta	38.5 (10)	80.8 (21)	0.0047	47.8 (32)	76.1 (51)	0.0014
Inferior vena cava	19.2 (5)	65.4 (17)	0.0020	44.8 (30)	70.1 (47)	0.0053
Left kidney	46.1 (12)	100 (26)	<0.0001	44.8 (30)	100 (67)	<0.0001
Right kidney	30.8 (8)	100 (26)	<0.0001	43.3 (29)	100 (67)	<0.0001
Spleen	34.6 (9)	88.5 (23)	0.0002	46.3 (31)	68.6 (46)	0.0149
Urinary bladder and Douglas pouch	57.7 (15)	100 (26)	0.0007	55.2 (37)	100 (67)	<0.0001
Uterus/prostate	50 (13)	92.3 (24)	0.0022	40.3 (27)	80.6 (54)	<0.0001

Results are expressed as percentage % (number of students)

ated several suggestions about various US applications for enhanced medical education [11].

Being a relatively new feature of our university's curricula, different teaching methods were applied; one being an optional abdominal US class through a full semester and one being an intensive abdominal US workshop. In both teaching styles, there was a 50% theoretical course and 50% hands-on sessions.

Medical students often demonstrate a quick initial learning phase when introduced to US. In a study by Bahner et al (2012), medical students could achieve basic competency in point-of-care US (POCUS) following a brief training session, suggesting that basic US skills can be rapidly acquired [12]. Our study yields findings that closely correspond with those outlined in this paper.

What are the benefits of an intensive workshop that is organized by students and consists of 6 hours of teaching? This method overcomes some of the difficulties universities may encounter while trying to include US classes in their curricula. The lack of capital resources and human resources can be a significant problem. However, an intensive workshop is much cheaper to organize than a full semester of teaching, and the lack of adequately trained teachers is resolved by the implication of peer teachers.

What advantages does a student-organized, 6-hour intensive workshop offer in the context of abdominal ultrasound learning curves? This approach addresses certain challenges that universities might face when integrating ultrasound classes into their curricula. The limitations stemming from financial and human resources can pose substantial obstacles. Nonetheless, organizing an intensive workshop proves to be a more cost-effective solution compared to a full semester of instruction. Furthermore, the involvement of peer teachers helps address the issue of a shortage of well-trained instructors.

The ideal student to teacher ratio of 1:1 is hard to obtain, so a 4:1 is an accepted alternative [13]. But even this ratio would mean a challenging number of well-trained trainers to achieve. Peer teaching is an excellent alternative; student-student interaction can facilitate the learning process. Performance among students receiving peer tutoring was comparable to that of students receiving traditional faculty instruction [14]. On the other hand, a workshop-style teaching does not overload students' already busy schedules. This type of learning also comes with a great amount of enthusiasm and determination from students, and it becomes increasingly important to adapt medical school curricula to students' desires.

At the same time, a more prolonged period dedicated to US learning has obvious benefits.

Mastery of US demands dedicated practice, feedback, and repetition. The concept of "deliberate practice," where learners actively seek feedback and focus on improving their weak points, is especially relevant to US training [15].

As our experience has shown, there were no differences found between the total number of structures identified by students after the course and after the workshop,

respectively. This lack of difference is probably because students taking part in the workshop type training were very determined, even though they practiced for fewer hours. The total number of US structures recognized after the course was significantly higher compared to the initial examination for both the optional course and the workshop. Prior to undergoing US training, students faced challenges in accurately identifying essential anatomical features and organs, reflecting a common hurdle in medical education. Identification rates even for the spleen and kidney were low, despite being in their 4th and 5th year of medical school; however, after completing their programme, their skills significantly improved.

The most challenging structures to identify at the beginning of the learning process were the caudate lobe, the hepatic hilum, and the pancreas in both groups. After completing the course, the percentage of students who were able to distinguish these features increased statistically. The results imply that incorporating US learning is an effective approach to supplementing fundamental science.

US teaching will likely become easier in future years. Handheld devices, which are less expensive than high-end units, are becoming more accessible and more performant, reducing the need for special settings. Also, new web-based sources of information e-learning and artificialintelligence-based teaching software are becoming more popular among students. Organizations such as WFUMB and EFSUMB also actively promote US learning for students, offering online knowledge and hands-on training sessions. In 2022, Hoppmann RA et al. published the first comprehensive document of recommendations for a basic US curriculum [16].

The main shortcoming of our paper is that it only analyzes abdominal US, and it is a single-center study, including a small number of students. We only analysed 2 generations of students; for more accurate results multiple generations should be followed. At the same time a better evaluation method should be applied for more reliable results.

Conclusions

Both extended and intensive US training approaches significantly improve the skills of medical students in abdominal ultrasound. These results underscore the importance of integrating diverse US training methods into medical education to enhance the competence of students in abdominal ultrasound.

Conflict of interest: none

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