PEDAGOGY

Simulation-based echocardiography learning contribution on training of medical residents

Contribution de l'apprentissage de l'échocardiographie par simulation à la formation des résidents en médecine

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Abstract

Introduction: Echocardiography is a pivotal exam in critically ill patients, a specific training is crucial. Medical residents often lack echocardiography practice.
Aim: This study aims to evaluate the impact of simulation-based training on medical residents' echocardiography mastery.
Methods: This interventional study was conducted among medical residents at the Simulation Center of the Faculty of Medicine in Monastir (CeSim) in January 2022. The intervention consisted of a theoretical training and a simulator-based practical training concerning echocardiography. Residents underwent evaluation before and after training through a "Pre-Test" and a "Post-Test," respectively, using a French-language questionnaire. Participation was entirely voluntary.
Results: A total of 28 medical residents participated in our study, with the majority being female (57.1%). The median age was 29 years (interquartile range: 28-31.75). Following training, the proportion of participants who reported having the necessary skills for echocardiography interpretation significantly increased ($p<0.05$). Respondents demonstrated significant improvements in their scores on theoretical tests and practical skills assessments. Concerning echocardiographic views, the percentage of participants who correctly identified the title of the parasternal small axis section increased from 53.6% before training to 100% after training ($p <10^{-3}$). Significant enhancements were observed in all parameters evaluating the practice of echocardiographic sections by respondents on a mannequin after training, encompassing time to obtain the view, view quality, image quality, visualization of structures, interpretability, and image stability ($p<10^{-3}$). There was a significant improvement in average response rates for echocardiographic clinical syndroms among medical residents before and after training. All participants emphasized the indispensability of ultrasound education in the training of physicians specializing in managing cardiopulmonary emergencies.
Conclusions: This study reports the beneficial role of simulation-based training in enhancing the mastery of medical residents in echocardiography. Incorporating such training methods into their learning curricula is advisable.

Key words: Simulation, echocardiography, medical education, ultrasound, training

Résumé

Introduction: L'échographie cardiaque est un examen essentiel chez les patients en état critique, nécessitant une formation spécifique. Les résidents en médecine manquent souvent de pratique.
Objectif: Cette étude vise à évaluer l'impact de la formation basée sur la simulation sur la maîtrise de l'échographie cardiaque par les résidents en médecine.
Méthodes: Cette étude a été menée parmi les résidents en médecine au Centre de Simulation de la Faculté de Médecine de Monastir (CeSim) en Janvier 2022. L'intervention comprenait une formation théorique et une formation pratique sur simulateur. Les résidents ont été évalués avant et après la formation par un "Pré-Test" et un "Post-Test", respectivement, à l'aide d'un questionnaire.
Résultats: Un total de 28 résidents en médecine a participé à notre étude, dont la majorité était féminine (57,1%). L'âge médian était de 29 ans ±28 (interquartile range: 28-31.75). Suite à la formation, la proportion de participants déclarant posséder les compétences nécessaires pour l'interprétation de l'échographie cardiaque a significativement augmenté. Il y a eu des améliorations significatives des scores aux tests théoriques et aux évaluations des compétences pratiques. Concernant les vues coupes échographiques, le pourcentage de participants identifiant correctement la coupe petit axe parasternale est passé de 53,6% avant la formation à 100% après la formation. Des améliorations significatives ont été observées sur dans les paramètres évaluant la pratique des coupes échographiques par les participants sur un mannequin après la formation, incluant le temps pour obtenir la vue coupe, la qualité de la vue coupe, la qualité de l'image, la visualisation des structures, l'interprétation et la stabilité de l'image. Il y a eu une amélioration significative du taux de réponse moyen moyenne pour les syndromes cliniques à l'échographie parmi les résidents avant et après la formation.
Conclusions: Cette étude souligne le rôle bénéfique de la formation basée sur la simulation pour améliorer la maîtrise de l'échographie cardiaque par les résidents en médecine. Il est conseillé d'intégrer de telles méthodes de formation dans leurs programmes d'apprentissage.

Mots clés: Echographie cardiaque, simulation, éducation médicale, entrainement

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Introduction

The limitations of physical examination are especially significant in the care of critically ill patients [1]. Echocardiography represents an important device for patients' management hospitalized in Intensive Care Unit (ICUs). It is easily accessible and reasonably priced. It serves as a comprehensive examination of heart, providing crucial information for the identification and therapy of the most prevalent health issues seen in critically ill patients. Echocardiography with Doppler is an increasingly utilized imaging technique by intensivists and anesthesiologists when evaluating critically ill patients. Incorporating echocardiography into the Intensive Care Unit (ICU) necessitates not only financial investment for acquiring dedicated equipment but also a commitment to staff education and training [2]. The High Health Authority (HAS) defines healthcare simulation education as "the utilization of equipment (such as mannequins or procedural simulators), virtual reality, or standardized patients to replicate healthcare scenarios or environments. This approach is employed to instruct healthcare professionals in diagnostic and therapeutic procedures, as well as to practice medical concepts or decision-making. It aligns with the ethical principle in medicine: 'Never perform a procedure on a patient for the first time'" [3]. Medical residents often have limited opportunities to practice echocardiography and are frequently relegated to observer roles. Consequently, there is a particular need for training in this area among residents. Numerous studies have demonstrated that simulation-based medical education can enhance student performance, knowledge acquisition, and confidence levels [4].
Our study aimed to assess the impact of simulation-based training in echocardiography among medical residents.

Methods

Study design and setting

This is an interventional pre-experimental study "before-after" conducted among medical residents at the Simulation Center of the Faculty of Medicine of Monastir (CeSim) in January 2022.

Study population

Medical residents of specialties confronted with situations of cardio-respiratory emergencies.

Data collection

Data collected concerned the characteristics of the residents, their level of training in echocardiography, theoretical and practical evaluation of echocardiography, and perceptions about improving ultrasound and echocardiography teaching. A simulator-based echocardiography "Schallware Ultrasound Simulator" was used to evaluate the echocardiographic practices [1]. It enables the " visiting " of the cardiac anatomy in its globality with high-quality synthetic imaging in transthoracic echocardiography for a normal heart and a variety of pathological situations.

Intervention program

The intervention consisted of theoretical and practical training concerning echocardiography.
Three experimented mentors performed the theoretical and practical formations. They were an associated Professors in Cardiology. The theoretical formation was performed using PowerPoint presentations and 40 videos. Concerning the practical formation, it was conducted using an ultrasound simulator and voluntaries voluntary patients.

Theoretical training

After an initial evaluation of the theoretical and practical knowledge of residents in echocardiography using a pre-test concerning the level of ultrasound training, knowledge concerning echocardiography, different views with which the participant was familiar, and title and legend of each view, the residents received a theoretical training of three hours in the form of presentation and videos illustrating the way of identification of the various normal and pathological echocardiographic views found in patients in critical condition and different ultrasound modalities (M-Mode Echocardiography, Two-Dimensional Echocardiography, Doppler Echocardiography).

Practical training

After the theoretical training, medical residents were left for three hours in groups of one to three per session in an environment that included the simulation mannequin. A qualified person (a cardiologist) was available at all times to help the residents in case of technical difficulties, at their request. First, the trainer demonstrated echocardiographic views in real time without comment. Secondly, the trainer repeated and interpreted each sequence. Thirdly, the learners explained the techniques while the trainer performed them. Finally, each candidate performed the sequence, receiving feedback in real time. At the end of this phase, a post-test identical to the pre-test was performed. It allowed us to evaluate the acquisition of knowledge and practices at the end of the training intervention. The post-test concerning the practices was timed and conducted by the evaluator. The residents were evaluated on their ability to obtain the five reference views in echocardiography (Parasternal Long-Axis View, Parasternal Short-Axis View, Apical four Chamber Views, and Subcostal View). For each view, five criteria were scored from 1 (bad) to 5 (very good): view quality, image quality, structure visualization, interpretability, and image stability, a. A score of 1/5 was attributed to all items if the resident could not find the view. Then, the participant was evaluated on his ability to identify: Severe severe hypovolemia, left ventricular failure, right ventricular failure, pericardial effusion/tamponade, left ventricular size and global systolic function, homogeneous or heterogeneous left ventricular contraction, right ventricular size and systolic function, size of the inferior vena cava and its respiratory variations.

Data analysis

We used the Statistical Package for the Social Sciences (SPSS) version 21.0 to analyze data. We calculated frequencies and percentages for the qualitative variables and the median (Interquartile range) for the quantitative variables. We used the Mac Nemar test to compare two qualitative variables between two matched groups, and the Wilcoxon test to compare two quantitative variables between two matched groups. A p-value of less than 0.05 was considered significant.

Ethical considerations

The participation was entirely voluntary. The course of the training was explained to all residents by describing the different stages of the training. A consent was taken from each participant before starting the study. Our investigation was anonymous and the confidentiality of the answers was guaranteed.

Results

Characteristics of the participants

In total, 28 medical residents participated in this study. The majority of them were female (57.1%). The median age of the students was 29 years (interquartile range: 28-31.75) years. The most frequent specialist speciality was anesthesia-intensive care (85.7%).

Participants' level of training in echocardiography

Only 14.3% of participants (n=4) had previously received training concerning echocardiography. This training was received as part of a diploma course (Supplementary Study Certificates, interuniversity diploma, university diploma...) for one participant, a short course (seminars, conferences...) for two participants, and training provided by a referral doctor in the department for one participant. These trainings were only theoretical for one participant and both theoretical and practical for two participants. Competence in performing echocardiography was self-assessed as quite good and bad by 23.8% and 76.2% of respondents respectively.

Theoretical evaluation of medical residents about echocardiography

Self-evaluation of echocardiography skills by medical residents before and after training (Table 1).
The percentage of participants reporting having skills required in the interpretation of echocardiography significantly increased before and after training ($p<0.05$). The percentage of respondents reporting that they could obtain different views in transthoracic echocardiography (TTE) significantly rose before and after training ($p<0.05$). (Table 1).

Comparison of average response rate for clinical syndromes and images of echocardiographic views among medical residents before and after training (Table 2).
The percentage of participants' responses for clinical syndromes and images of echocardiographic views among residents before and after training are described in (Table 2).

Practical evaluation of echocardiography on the simulation mannequin

All parameters (time of obtaining the View view, quality of the View view, image quality, visualization of structures, interpretability, image stability) evaluating the practice of echocardiographic views by participants on a mannequin significantly improved after training (p<10-3). At the end of the simulation mannequin training, the median time of obtaining views was less than in less or equal to 10 seconds by all participants (Table 3).

The evaluation of heart function (Left ventricular size and global systolic function, Right ventricular size and systolic function) and of the capacity to identify cardiac abnormalities (severe hypovolemia, left ventricular failure right ventricular failure, pericardial effusion/tamponade, homogeneous or heterogeneous, left ventricular contraction) before and after training during the practice of echocardiographic views by medical residents on the mannequin showed a significant improvement in all of these parameters (p <10-3) (Table 4).

Perceptions about improving ultrasound and echocardiography teaching.

All participants (100%) thought that teaching ultrasound is a necessary part of the training of physicians in specialities that deal with cardiopulmonary emergencies. Perceptions of medical residents about improving ultrasound and echocardiography teaching are described in Table 5.

Discussion

Our study highlighted the importance of simulation in the learning of echocardiography. Respondents showed significant improvements in their scores after training on theoretical tests and practical skills.
Point-of-care ultrasound (POCUS) involves focused examinations that allow real-time integration of both anatomical and functional findings into diagnostic and therapeutic approaches. Critical Care Ultrasound (CCUS) is an application of POCUS specifically aimed at managing critically ill patients [2].

Table 1. Self-evaluation of echocardiography skills by medical residents before and after training, Monastir (Tunisia), February 2022

	Before training n(%)		**After training** n(%)		**p-value**
	No	Yes	No	Yes	
Self-evaluation of having skills required in the interpretation of echocardiography					
Left ventricular size and global systolic function	19 (67.9)	9 (32.1)	1 (3.6)	27 (96.4)	**<10^{-3}**
Homogeneous or heterogeneous left ventricular contraction	13 (46.4)	15 (53.6)	2 (7.1)	26 (92.9)	**0.001**
Right ventricular size and systolic function	25 (89.3)	3 (10.7)	3 (10.7)	25 (89.3)	**<10^{-3}**
Identification of pericardial effusion / tamponade	11 (39.3)	17 (60.7)	2 (7.1)	26 (92.9)	**0.012**
Size of the inferior vena cava and its respiratory variations	10 (35.7)	18 (64.3)	2 (7.1)	26 (92.9)	**0.021**
Color Doppler evaluation of severe valvular insufficiency	26 (92.9)	2 (7.1)	3 (10.7)	25 (89.3)	**<10^{-3}**
None	24 (85.7)	4 (14.3)	27 (96.4)	1 (3.6)	NA*
Different views that the participant know in trans thoracic echocardiography (TTE)					
Parasternal long axis section	5 (17.9)	23 (82.1)	0 (0)	28 (100)	NA*
Short axis parasternal section	8 (28.6)	23 (82.1)	0 (0)	28 (100)	NA*
Apical 4/5 cavities section	18 (64.3)	10 (35.7)	0 (0)	28 (100)	NA*
Apical 2/3 cavities section	23 (82.1)	5 (17.9)	4 (14.3)	24 (85.7)	**<10^{-3}**
Sub-costal 4 cavities section	11 (39.3)	17 (60.7)	0 (0)	28 (100)	NA*
Subcostal section (inferior vena cava incidence)	8 (28.6)	20 (71.4)	0 (0)	28 (100)	NA*
None	25 (89.3)	3 (10.7)	0 (0)	28 (100)	NA*
Different views that the participant can obtain in trans thoracic echocardiography (TTE)					
Parasternal long axis section	25 (3)	3 (10.7)	1 (3.6)	27 (96.4)	**<10^{-3}**
Short axis parasternal section	23 (89.3)	3 (10.7)	2 (7.1)	26 (92.9)	**<10^{-3}**
Apical 4/5 cavities section	23 (82.1)	5 (17.9)	1 (3.6)	27 (96.4)	**<10^{-3}**
Apical 2/3 cavities section	27 (96.4)	1 (3.6)	16 (57.1)	12 (42.9)	**0.001**
Sub-costal 4 cavities section	21 (75)	7 (25)	8 (20)	20 (71.4)	**0.001**
Subcostal section (inferior vena cava incidence)	14 (50)	14 (50)	1 (3.6)	27 (96.4)	**0.001**
None	18 (64.3)	10 (35.7)	25 (89.3)	3 (10.7)	0.092
Do cardiorespiratory interactions (spontaneously ventilated or ventilated patient) influence echocardiographic measurements?	1 (3.6)	27 (96.4)	0 (0)	28 (100)	NA*
What parameters are routinely assessed during an echocardiographic examination?					
Heart cavities	5 (17.9)	23 (82.1)	0 (0)	28 (100)	NA*
Systolic function	3 (10.7)	25 (89.3)	0 (0)	28 (100)	NA*
Diastolic function	6 (21.4)	22 (78.6)	1 (3.6)	27 (96.4)	NA*
valve status	6 (21.4)	22 (78.6)	0 (0)	28 (100)	NA*
preload-dependence (* ΔITVao * ØVCI /VCS, LV (left ventricle) size*	13 (46.4)	15 (53.6)	5 (17.9)	23 (82.1)	**0.03**
pericardium	4 (14.3)	24 (85.7)	1 (3.6)	27 (96.4)	NA*
I don't know	25 (89.3)	3 (10.7)	22 (78.6)	6 (21.4)	NA*
Can you study the respiratory variability of the IVC diameter on TTE?	15 (53.6)	13 (46.4)	0 (0)	28 (100)	NA*
Can you analyze LV systolic function by TTE?	23 (82.1)	5 (17.9)	0 (0)	28 (100)	NA*
Can you analyze LV diastolic function by TTE and more specifically, identify with the measurements an increase in LV filling pressures (LVFP)?	26 (92.9)	2 (7.1)	3 (10.7)	25 (89.3)	**<10-3**
Can you analyze right heart function by TTE?	26 (92.9)	2 (7.1)	0 (0)	28 (100)	NA*
Can you identify signs of acute pulmonary heart disease on TTE?	20 (71.4)	8 (28.6)	2 (7.1)	26 (92.9)	**<10-3**
Can you identify a pulmonary hypertension on TTE?	25 (89.3)	3 (10.7)	7 (25)	21 (75)	**<10-3**
Can you perform the different measurements of the heart chambers (DTSVG ,DTDVG ,DTSVD, DTDVD, OG surface, SIVD, SIVS....)?	25 (89.3)	3 (10.7)	3 (10.7)	25 (89.3)	**<10-3**
Do you know the interpretation of each of these different measurements (normal ,in favor of dilatation, hypertrophy ......)?	25 (89.3)	3 (10.7)	5 (17.9)	23 (82.1)	**<10-3**
Can you identify severe valve insufficiency on DOPPLER COLOR TTE?	24 (85.7)	4 (14.3)	4 (14.3)	24 (85.7)	**<10-3**
Can you identify a pericardial effusion and specify its abundance?	17 (60.7)	11 (39.3)	3 (10.7)	25 (89.3)	**0.001**
Can you identify a tamponade on TTE?	19 (67.9)	9 (32.1)	0 (0)	28 (100)	**<10-3**

***NA**: Not applicable

Table 2. Comparison of average response rate for clinical syndroms and images of echocardiographic views among medical residents before and after training, Monastir (Tunisia), February 2022

	Before training n(%)		**After training** n(%)		**p-value**
	False response	True response	False response	True response	
Which of the following echocardiographic signs is (are) in favor of each of these clinical syndromes					
1-Severe hypovolemia					
Small, hypokinetic ventricular cavities	1 (3.6)	27 (96.4)	4 (14.3)	24 (85.7)	NA*
Small, hypekinetic ventricular cavities	19 (67.9)	9 (32.1)	4 (14.3)	24 (85.7)	**$<10^{-3}$**
Small diameter IVC with large respiratory variations	2 (7.1)	26 (92.9)	0 (0)	28 (100)	NA*
2-Left ventricular failure					
Segmental abnormality of contractility suggestive of myocardial ischemia	12 (42.9)	16 (57.1)	0 (0)	28 (100)	NA*
Left diastolic dysfunction	11 (39.3)	17 (60.7)	3 (10.7)	25 (89.3)	**0.03**
Dilatation of the LV cavity suggestive of acute cardiac injury	8 (28.6)	20 (71.4)	1 (3.6)	27 (96.4)	NA*
3-Right ventricular failure					
Dilated, compressible IVC	9 (32.1)	19 (67.9)	0 (0)	28 (100)	NA*
Acute pulmonary heart: LV dilatation and paradoxical septum	5 (17.9)	23 (82.1)	0 (0)	28 (100)	NA*
Isolated dilatation of the VD suggestive of a VD infarction	18 (64.3)	10 (35.7)	3 (10.7)	25 (89.3)	**$<10^{-3}$**
4- Tamponade					
Pericardial effusion	2 (7.1)	16 (92.9)	0 (0)	28 (100)	NA*
Diastolic collapse of the left cavities	16 (57.1)	12 (42.9)	4 (14.3)	24 (85.7)	**0.004**
Dilated, compressible IVC	7 (25)	21 (75)	2 (7.1)	26 (92.9)	NA*
5- Massive acute mitral insufficiency					
Small LV (acute valvular disease)	3 (10.7)	25 (89.3)	3 (10.7)	25 (89.3)	NA*
Massive regurgitation on color Doppler	2 (7.1)	26 (92.9)	0 (0)	28 (100)	NA*
Decreased LV function	2 (7.1)	26 (92.9)	0 (0)	28 (100)	NA*
6- Cardiocirculatory inefficiency during resuscitation					
Tamponade or acute pulmonary heart (massive pulmonary embolism)	13 (46.4)	15 (53.6)	2 (7.1)	26 (92.9)	**0.001**
LV function (cardiac arrest, collapsed, hyperkinetic)	11 (39.3)	17 (60.7)	0 (0)	28 (100)	NA*
LV function (cardiac arrest, collapsed, hyperkinetic)	14 (50)	14 (50)	2 (7.1)	26 (92.9)	**0.002**
7- Cardiocirculatory inefficiency after resuscitation					
LV segmental contraction abnormality suggestive of myocardial ischemia	3 (10.7)	25 (89.3)	1 (3.6)	27 (96.4)	NA*
LV segmental contraction abnormality suggestive of myocardial ischemia	11 (39.3)	17 (60.7)	2 (26)	26 (92.9)	NA*
For each of the following views, indicate its title and legend:					
1-Section 1					
Title: Apical section 4 cavities	7 (25)	21 (75)	0 (0)	28 (100)	NA*
Legend 1: right ventricle	5 (17.9)	23 (82.1)	0 (0)	28 (100)	NA*
Legend 2 : left ventricle	4 (14.3)	24 (85.7)	0 (0)	28 (100)	NA*
Legend 3: right atrium	4 (14.3)	24 (85.7)	0 (0)	28 (100)	NA*
Legend 4: left atrium	4 (14.3)	24 (85.7)	1 (3.6)	27 (96.4)	NA*
2-Section 2					
Title: Parasternal long axis section	14 (50)	14 (50)	0 (0)	28 (100)	NA*
Legend 1: right ventricle	8 (28.6)	20 (71.4)	0 (0)	28 (100)	NA*
Legend 2: ascending aorta	5 (17.9)	23 (82.1)	0 (0)	28 (100)	NA*
Legend 3 : left ventricle	9 (32.1)	19 (67.9)	0 (0)	28 (100)	NA*
Legend 4: right atrium	12 (42.9)	16 (57.1)	1 (3.6)	27 (96.4)	NA*
Legend 5: descending thoracic aorta	16 (57.1)	12 (42.9)	2 (7.1)	26 (92.9)	**0.003**
3-Section 3					
Title: Parasternal small axis section	13 (46.4)	15 (53.6)	0 (0)	28 (100)	**<10-3**
Legend 1: right ventricle	14 (50)	14 (50)	0 (0)	28 (100)	NA*
Legend 2: left ventricle	15 (53.6)	13 (46.4)	0 (0)	28 (100)	NA*
4-Section 4					
Title: Apical section of the two cavities	22 (78.6)	6 (21.4)	3 (10.7)	25 (89.5)	**<10-3**
Legend 1: left ventricle	22 (78.6)	6 (21.4)	4 (14.3)	24 (85.7)	**<10-3**
Legend 2 : left atrium	24 (85.7)	4 (14.3)	6 (21.4)	22 (78.6)	**<10-3**
5-Section 5					
Title: Subcostal View	21 (75)	7 (25)	0 (0)	28 (100)	NA*
Legend 1: right atrium	15 (53.6)	13 (46.4)	1 (3.6)	27 (96.4)	**0.001**
Legend 2: right ventricle	16 (57.1)	12 (42.9)	1 (3.6)	27 (96.4)	**<10-3**
Legend 3: left ventricle	18 (64.3)	10 (35.7)	2 (7.1)	26 (92.9)	**<10-3**
Legend 4: left atrium	18 (64.3)	10 (35.7)	4 (14.3)	24 (85.7)	**< 10-3**

***NA**: Not applicable

Table 3. Score analysis of the practice of echocardigraphic views'parameters by medical residents on a mannequin before and after training, Monastir (Tunisia), February 2022

	Time of obtaining the View (seconds)			Quality of the View			Image quality			Visualization of structures			Interpretability			Image stability		
	Before training (median [IQR*])	After training (median [IQR*])	p	Before training (median [IQR*])	After training (median [IQR*])	p	Before training (median [IQR*])	After training (median [IQR*])	p	Before training (median [IQR*])	After training (median [IQR*])	p	Before training (median [IQR*])	After training (median [IQR*])	p	Before training (median [IQR*])	After training (median [IQR*])	p
Parasternal long axis views	40 [35,40]	10 [8,14.7]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,2.75]	5 [4,5]	$<10^{-3}$	1 [1,2]	4 [4,4.75]	$<10^{-3}$
Parasternal Short-Axis View	25 [25,28]	5 [5,8]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,2]	4 [4,5]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,2]	4 [4,5]	$<10^{-3}$	1.5 [1,2]	4 [4,4]	$<10^{-3}$
Apical four Chamber Views	35 [30,35]	10 [10,13]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,2]	4 [3.25,5]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,2]	5 [4,5]	$<10^{-3}$	2 [1,2]	4 [4,5]	$<10^{-3}$
Apical View 2/ 3 cavities	25 [20,29]	5 [5,7.5]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	1 [1,2]	4 [4,5]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,2]	4 [4,5]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$
Subcostal View	30 [30,35]	10 [10,10]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	1 [1,2]	4 [4,5]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$	2 [1,3]	4 [4,5]	$<10^{-3}$	2 [1,2]	4 [4,4]	$<10^{-3}$

* IIQ: Interquartile range

Table 4. Evaluation of heart function and the capacity to identify cardiac abnormalities (clinical syndroms) during the practice of echocardigraphic views by medical residents on a mannequin before and after training, Monastir (Tunisia), February 2022

	Before training n(%)		**After training** n(%)		**p-value**
	No	Yes	No	Yes	
When performing echocardiography, was the participant able to identify					
Severe hypovolemia	25 (89.3)	3 (10.7)	4 (14.3)	24 (85.7)	$<\mathbf{10^{-3}}$
Left ventricular failure	26 (92.9)	2 (7.1)	2 (7.1)	26 (92.9)	$<\mathbf{10^{-3}}$
Right ventricular failure	27 (96.4)	1 (3.6)	5 (17.9)	23 (82.1)	$<\mathbf{10^{-3}}$
Pericardial effusion / tamponade	23 (82.1)	5 (17.9)	2 (7.1)	26 (92.9)	$<\mathbf{10^{-3}}$
Left ventricular size and global systolic function	27 (96.4)	1 (3.6)	2 (7.1)	26 (92.9)	$<\mathbf{10^{-3}}$
Homogeneous or heterogeneous left ventricular contraction	26 (92.9)	2 (7.1)	2 (7.1)	26 (92.9)	$<\mathbf{10^{-3}}$
Right ventricular size and systolic function	27 (96.4)	1 (3.6)	8 (28.6)	20 (71.4)	$<\mathbf{10^{-3}}$
Size of the inferior vena cava and its respiratory variations	19 (67.9)	9 (32.1)	0 (0)	28 (100)	**NA***

***NA**: Not applicable

Our study revealed a significant enhancement in echocardiography interpretation skills, which positively correlated with the number of exams conducted. Although ultrasound (US) reduces radiation exposure and offers real-time imaging in various planes, it necessitates substantial experience [4]. Simulation training helps in comprehending cardiac anatomy and expedites knowledge acquisition and skill development. Encouraging the integration of such simulations into training programs is beneficial, as they offer a low-stress environment for learning and the opportunity to practice clinical problem-solving using various scenarios [5]. In our study, we observed a substantial improvement in accurate responses related to clinical syndromes and echocardiographic views before and after training among medical residents. Assessment methods encompass traditional measures like continuing medical education exercises or multiple-choice exams and simulation, which serve as a valuable tool for evaluating clinical competencies essential for safe patient care [6]. In the emergency department, the physician performing echocardiography should have a solid knowledge of cardiology and the ability to effectively incorporate echo information into the decision-making process. Echocardiography is crucial for promptly identifying cardiovascular pathologies like hypovolemia, severe global left ventricular dysfunction, and pericardial effusion, aiding in better patient management [7]. Simulation-based education has demonstrated its effectiveness in training physicians in Echocardiography. The success of these training methods suggests that simulator-based training has the potential to enhance education and patient care. Incorporating simulators into clinical training curricula can offer a safe environment for skill acquisition, thereby reducing patient risk [8]. Our study revealed significant improvements in assessing echocardiographic views on a mannequin, including parameters such as view acquisition time, quality, image quality, structure visualization, interpretability, and image stability, both before and after training (p < 10-3) [9]. Additionally, we observed significant progress in evaluating heart function, encompassing left ventricular size, global systolic function, right ventricular size, systolic function, and the identification of cardiac abnormalities like severe hypovolemia, left ventricular failure, right ventricular failure, pericardial effusion/tamponade, and the nature of left ventricular contraction, both before and after training (p < 10-3) [9]. Numerous studies have highlighted the efficacy of simulator-based training in enhancing interpretability scores and practical image acquisition skills [10, 11, 12]. For instance, a study involving 35 trainees in emergency medicine, anesthesiology, or cardiology found that a self-training program using a simulator significantly improved interpretability scores [10]. Another study demonstrated that students with no prior experience in echocardiography were able to achieve a high percentage of interpretable images after a short training period and supervised ultrasounds [12]. Simulation-based ultrasound training, particularly in point-of-care (POC) protocols, has shown that practical skills can significantly improve, enhancing image acquisition, quality, and interpretation, and is a valuable tool for learning new diagnoses [13]. In our study, most residents lacked prior echocardiography training, but their practical skills significantly improved following interactive e-learning and a 4-hour hands-on training session [11]. The simulator provided a realistic representation of cardiac anatomy and aided in diagnosing various pathologies commonly encountered by intensivists [11]. Ultrasound (US) can offer crucial information about cardiac contractility and detect pathologies like pericardial effusion or tamponade, which require immediate intervention. Simulation-based medical education has demonstrated its positive impact on confidence, knowledge, and performance, ultimately leading to high-quality patient care [14]. The ethical and pedagogical advantages of simulation are well-recognized, promoting safe and enjoyable training for medical students at different training levels. According to the Kirkpatrick model, learning assessment encompasses four levels: student satisfaction, skill acquisition, practice change, and clinical impact [15]. Transferring knowledge between simulation and real-world settings can be challenging to evaluate [16]. Having an instructor present during training can be beneficial, facilitating corrections and improvements in the acquired skills [16]. Future research should include the assessment of echocardiographic images acquired from real patients following simulation-based training. Technological advancements, including those related to echocardiography, are critical for enhancing simulation experiences. Incorporating features like colour Doppler can make the simulator more realistic, translating the skills gained through simulation into optimal clinical care [8]. All participants in our study recognized the importance of ultrasound education, particularly for physicians specializing in cardiopulmonary emergencies.

While a 2012 meta-analysis found no clear evidence that simulation-based education consistently improved students' clinical practice skills, some studies proposed combining various teaching methods [17].

In summary, our study underscores the significant value of ultrasound training for medical professionals working in specialities related to cardiopulmonary emergencies.

Table 5. Perceptions of medical residents about improving ultrasound and echocardiography teaching, Monastir (Tunisia), February 2022

Statements	Respondents (n (%))
Teaching ultrasound is a necessary part of the training of physicians in specialties that deal with cardiopulmonary emergencies	
No	0 (0)
Yes	28 (100)
It would be necessary to include mandatory diploma training in echocardiography during the residency program	
Strongly agree	21 (75)
Agree	7 (25)
Somewhat agree	0 (0)
Strongly disagree	0 (0)
This training should be included during	
1st year of residency	5 (17.9)
2nd year of residency	9 (32.1)
3rd year of residency	13 (46.4)
4th year of residency	1 (3.6)
Concerning the usefulness of the different types of ultrasound education	
Lectures	
Indispensable	13 (46.4)
Useful	13 (46.4)
Unnecessary	2 (7.1)
Practical workshops	
Indispensable	26 (92.9)
Useful	2 (7.1)
Unnecessary	0 (0)
Ultrasound seminars	
Indispensable	21 (75)
Useful	7 (25)
Unnecessary	0 (0)
Simulation sessions	
Indispensable	23 (82.1)
Useful	5 (17.9)
Unnecessary	0(0)
There is a need to develop new continuing education programs in echocardiography	
No	0 (0)
Yes	28 (100)
Concerning the usefulness of introducing ultrasound knowledge tests among medical residents	
Theoretical knowledge tests	
Indispensable	14 (50)
Useful	14 (50)
Unnecessary	0 (0)
Practical knowledge control	
Indispensable	18 (64.3)
Useful	10 (35.7)
Unnecessary	0 (0)
Concerning the introduction of these different ways of evaluating ultrasound knowledge	
Practical test, at the patient's bed	
Very appropriate	24 (85.7)
Appropriate	4 (14.3)
Inappropriate	0 (0)
Practical test, on an ultrasound simulator	
Very appropriate	22 (78.6)
Appropriate	6 (21.4)
Inappropriate	0 (0)
Practical test, on a voluntee	
Very appropriate	15 (53.6)
Appropriate	12 (42.9)
Inappropriate	1 (3.6)
Theoretical test, by multiple-choice questions	
Very appropriate	12 (42.9)
Appropriate	15 (53.6)
Inappropriate	1 (36)
Theoretical test, by essay question	
Very appropriate	9 (32.1)
Appropriate	15 (53.6)
Inappropriate	4 (14.3)
Theoretical control, by clinical case	
Very appropriate	10 (35.7)
Appropriate	17 (60.7)
Inappropriate	1 (3.6)

Point-of-care ultrasound (POCUS) offers goal-oriented examinations, enabling real-time integration of both anatomical and functional findings into diagnostic and therapeutic approaches, with its critical care ultrasound (CCUS) application specifically catering to critically ill patients [2].

Conclusions

Our study demonstrates the short-term effectiveness and feasibility of simulator-based echocardiography training at the Simulation Center of the Faculty of Medicine of Monastir. Participants showed significant improvement in their scores on theoretical tests and practical skills. Simulation is an excellent method that addresses novices facilitating their training in a short time. It allows one to acquire this technique in a secure environment, to obtain the experience and the confidence necessary to perform it on a patient in a real situation. More studies are needed to evaluate the effective clinical practice and to assess the durability of the training.

References

1. Manual-en-original-49b6638945633463e5a7df8cf33a7128.pdf [Internet]. [cité 13 mars 2022]. Disponible sur: https://assets.schallware.de/uploads/downloads/14/pdfs/manual-en-original-49b6638945633463e5a7df8cf33a7128.pdf
2. Arntfield RT, Millington SJ, Ainsworth CD, Arora RC, Boyd J, Finlayson G, et al. Canadian recommendations for critical care ultrasound training and competency. Can Respir J. 2014;21(6):341-5.
3. Neskovic AN, Edvardsen T, Galderisi M, Garbi M, Gullace G, Jurcut R, et al. Focus cardiac ultrasound: the European Association of Cardiovascular Imaging viewpoint. European Heart Journal - Cardiovascular Imaging. 1 sept 2014;15(9):956-60.
4. Sidhu HS, Olubaniyi BO, Bhatnagar G, Shuen V, Dubbins P. Role of simulation-based education in ultrasound practice training. J Ultrasound Med. mai 2012;31(5):785-91.
5. Sharma V, Fletcher SN. A review of echocardiography in anaesthetic and peri-operative practice. Part 2: training and accreditation. Anaesthesia. août 2014;69(8):919-27.
6. Levine AI, Schwartz AD, Bryson EO, Demaria S. Role of simulation in U.S. physician licensure and certification. Mt Sinai J Med. févr 2012;79(1):140-53.
7. Neskovic AN, Hagendorff A, Lancellotti P, Guarracino F, Varga A, Cosyns B, et al. Emergency echocardiography: the European Association of Cardiovascular Imaging recommendations. European Heart Journal - Cardiovascular Imaging. 1 janv 2013;14(1):1-11.
8. Dayton JD, Groves AM, Glickstein JS, Flynn PA. Effectiveness of echocardiography simulation training for paediatric cardiology fellows in CHD. Cardiol Young. avr 2018;28(4):611-5.
9. Vignon P, Dugard A, Abraham J, Belcour D, Gondran G, Pepino F, et al. Focused training for goal-oriented hand-held echocardiography performed by noncardiologist residents in the intensive care unit. Intensive Care Med. oct 2007;33(10):1795-9.
10. Providing Initial Transthoracic Echocardiography Training for Anesthesiologists: Simulator Training Is Not Inferior to Live Training - ScienceDirect [Internet]. [cité 15 avr 2022]. Disponible sur: https://www.sciencedirect.com/science/article/abs/pii/S1053077013004217
11. Heiberg J, Hansen LS, Wemmelund K, Sørensen AH, Ilkjaer C, Cloete E, et al. Point-of-Care Clinical Ultrasound for Medical Students. Ultrasound Int Open. nov 2015;1(2):E58-66.
12. Frederiksen CA, Juhl-Olsen P, Nielsen DG, Eika B, Sloth E. Limited intervention improves technical skill in focus assessed transthoracic echocardiography among novice examiners. BMC Med Educ. déc 2012;12(1):65.
13. Rambarat CA, Merritt JM, Norton HF, Black E, Winchester DE. Using Simulation to Teach Echocardiography: A Systematic Review. Simul Healthc. déc 2018;13(6):413-9.
14. Amini R, Stolz LA, Javedani PP, Gaskin K, Baker N, Ng V, et al. Point-of-care echocardiography in simulation-based education and assessment. Adv Med Educ Pract. 31 mai 2016;7:325-8.
15. Kirkpatrick DL. Evaluating Training Programs. The Four Levels. Berrett-Koehler Organizational Performance Series. Berrett-Koehler Publishers, Inc; 1994.
16. Bernard A, Chemaly P, Dion F, Laribi S, Remerand F, Angoulvant D, et al. Evaluation of the efficacy of a self-training programme in focus cardiac ultrasound with simulator. Arch Cardiovasc Dis. oct 2019;112(10):576-84.
17. Sidhu HS, Olubaniyi BO, Bhatnagar G, Shuen V, Dubbins P. Role of Simulation-Based Education in Ultrasound Practice Training. Journal of Ultrasound in Medicine. mai 2012;31(5):785-91.
18. McSparron JI, Michaud GC, Gordan PL, Channick CL, Wahidi MM, Yarmus LB, et al. Simulation for Skills-based Education in Pulmonary and Critical Care Medicine. Ann Am Thorac Soc. avr 2015;12(4):579-86.
19. Hempel C, Turton E, Hasheminejad E, Bevilacqua C, Hempel G, Ender J, et al. Impact of simulator-based training on acquisition of transthoracic echocardiography skills in medical students. Ann Card Anaesth. sept 2020;23(3):293-7.