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Original Article

Pocket Size Ultra-Sound versus Cardiac Auscultation in Diagnosing Cardiac Valve Pathologies: A Prospective Cohort

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Abstract

Background: Pocket-size ultrasound devices are used to perform focused ultrasound studies (POCUS). We compared valve malfunction diagnosis rate by cardiac auscultation to POCUS (insonation), both conducted by medical students. **Methods:** A prospective cohort study was conducted among subjects with and without clinically relevant valve dysfunction. Inclusion criteria for subjects with a clinically relevant valve dysfunction was based on the presence of at least one moderate severity valve pathology identified by echocardiography. Three final-year medical students examined the patients. Each subject underwent auscultation and a POCUS using a pocket-size ultrasound machine. Sensitivity and specificity were calculated. **Results:** The study included 56 patients. In 18 patients (32%) no valve pathology was found. Nineteen patients (34%) had at least two valvular pathologies. Sixty valve lesions were present in the entire cohort. Students' sensitivity for detecting any valve lesion was 32% and 64% for auscultation and insonation, respectively, and specificity was similar. The sensitivity for diagnosing mitral regurgitation, mitral stenosis, and aortic regurgitation rose significantly by using POCUS compared to auscultation alone. When using POCUS, students identified valvular pathologies in 22 cases (39%) from the patients with at least two valve dysfunctions, and none when using auscultation. **Conclusions:** Final-year medical students' competency to detect valve dysfunction by performing cardiac auscultation is poor. Cardiac ultrasound-focused training significantly improved medical students' sensitivity for diagnosing a variety of valve pathologies.

Key Words: Auscultation; Diagnosis; Insonation; Medical students; Pocket ultrasound device; Point-of-care ultrasound; Valve disease (Source: MeSH-NLM).

Background

For the last almost 200 years, physical examination has been based on inspection, percussion, palpation, and auscultation. The physical examination is immediate, does not require any special technological equipment, and is a part of the early stages of medical students training. However, the diagnostic accuracy of the physical examination is low, at least for a significant number of cardiac pathologies, even among specialists.[1-4]

Improvements in technology have enabled the development of small ultrasound devices with high resolution. These miniature devices can be used to perform focused ultrasound studies, termed point-of-care ultrasound (POCUS), as an extension of the physical examination for the diagnosis of cardiac as well as lung and abdominal pathologies after brief training.[5-11] Robust data has been collected for the last fifteen years showing the benefits of adding POCUS to the physical examination in the diagnosis of cardiac pathologies performed by medical students, residents, non-cardiologist physicians, and cardiologists.[12] Furthermore, using POCUS, medical students were able to better diagnose cardiac diseases compared to cardiologists with vast experience who conducted a physical examination based on cardiac auscultation.[11] Stokke et al. demonstrated that 21 medical students improved their diagnostic rate of clinically relevant valvular lesions (from 49% based on auscultation and 64% based on POCUS) after only four hours training in cardiac ultrasound.[13] As such, ultrasound is gradually being incorporated into the curriculum of medical schools worldwide.[14] Finally, insonation, meaning "exposure to or the use of ultrasound", has been proposed to become the fifth pillar of the physical examination after inspection, percussion, palpation, and auscultation.[15]

To date, assessment of the additional value of insonation for diagnosing left-sided valvular dysfunction has been evaluated on patients with single valvular lesions.[3] In the current study, we aim to compare auscultation to insonation in the diagnosis of valve malfunction in a population in which some patients had multiple valve lesions, performed by medical students after a relatively short training in cardiac ultrasound. We hypothesized that insonation will outperform auscultation in the diagnosis of valvular pathologies.

Methods

Study population.

Three students in their final year of medical school received twelve hours of training on the operation of a pocket-size ultrasound device (PUD) in order to diagnose common valve disorders. The three students were part of a pilot study with the purpose of evaluating the convenience of implementing this type of course as part of a one-week clerkship in cardiology. The students were not picked by their performance or by their grades but rather arbitrarily. The training process took place in a series of two-hour sessions over the course of approximately a month, beginning with a one-hour lecture on the physics of ultrasound, cardiac ultrasound anatomy, and the examination technique. Next, there was a three-hour bedside-guided lesson on main cardiac ultrasound views, identifying anatomic points, and a two-hour review of normal and abnormal echocardiographic cases focused on valve pathologies in the echocardiography lab. These were followed by one hour of hands-on exercise using PUD under the guidance of an echocardiography technician and seven additional hours of practice on volunteer healthy subjects. Prior to the initiation of the study, the students listened to sound characteristics of murmurs on a

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Blaufuss sound builder website under supervision and explanation by the principal investigator.

The students were proficient in cardiac auscultation that had been taught in the previous years and had used it as part of the physical examination they performed in different teaching scenarios during the last three years of the medical school.

The session on auscultation was an hour long and focused on the recognition of the individual pathologies and the characteristics that allow the examiner to differentiate pathologies that cause systolic and diastolic murmurs. The auscultatory skills of the students were not assessed prior to the initiation of the study.

The recruitment of subjects was conducted through the Cardiology Section at Soroka Medical Center. Recruitment was based on the presence of at least one valve pathology of at least moderate severity identified on recent echocardiography study that was required for clinical reasons. A control group of subjects without valve disease was recruited as well and was matched by gender and age. Echocardiography is the most efficient tool to diagnose valve disease; accordingly, we use it as the gold-standard method to compare students' ability to diagnose valve disease and rather than the physical examination of expert clinicians which, when based on auscultation, can misdiagnose almost half of the clinically significant valve diseases.[2, 11, 12]

The nature of the study and the examinations were explained to all research subjects. A signed informed consent was obtained from all subjects. The study was approved by the local ethics committee.

The device.
The miniature device used was the General Electric Vscan ultrasound device, measuring 28 × 73 × 135 mm. The combined weight of the device and transducer is 390 grams. The monitor of the device is 3.5 inches wide, with a resolution of 320×240 pixels, and provides two-dimensional and conventional color Doppler, but lacks spectral Doppler. The device is able to save still images and videos in a flash-card memory.

Data collection.
The students, who were unaware of the echocardiography results, performed two examinations on each subject: first a physical examination that included cardiac auscultation, the results of which were recorded on an examination form. Next, the subjects underwent a POCUS performed with the miniaturized device, and the test results were documented on the examination form (same form as auscultation reports) that noted whether any disorder of the mitral valve or the aortic valve (regurgitation or stenosis) had been found. This sequence was chosen in order to avoid influence of the results of POCUS on the auscultation results. The students were notified that patient may or may not have multiple valves lesions. The three examiners were blinded to the results of their classmates and were alone while performing the examinations on the subjects. The studies were conducted within two months from the first patient enrollment. Demographic and clinical data and standard echocardiogram results were taken from the computerized hospital files of the subjects.

Statistical analysis.
The data were processed with SPSS version 18 software. The demographic and clinical characteristics of the study population were described. The categorical variables were described by percentage and number. The quantitative variables were presented by mean and standard deviation, and the nonparametric variables were described by median and range.

Sensitivity was defined as the percentage of subjects correctly identified by the student as suffering from a valve disorder. Specificity was defined as correct identification of the absence of valve pathology. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the POCUS findings were calculated, against the echocardiographic study carried out by an experienced examiner. The kappa test was used to assess the degree of agreement between the findings of the POCUS and the findings of the echocardiography study for each of the students, with a value above 0.6 considered good agreement and a value above 0.8 considered very good agreement.
In order to address the question of which factors are more accurate predictors (of pathology or absence of pathology) in POCUS compared to physical examination, an ordinal generalized estimating equation (GEE) model was used. The definition of effect of the model is as follows: -1 – Physical examination provides more accurate identification (of pathology or absence of pathology); 0 – There is no difference between POCUS and physical examination in terms of identification (of pathology or absence of pathology); +1 – POCUS provides more accurate identification (of pathology or absence of pathology).

In the performance of the model, adjustments were made for tests conducted on the same patient, as well as by the same operator. Variables with two-sided p-value < 0.1 in the univariate analysis or as clinically relevant were introduced into the multivariate analysis including age, body mass index (BMI), gender, type of valve pathology, and severity. A two-sided p-value <0.05 was considered significant.

Sample size considerations were as follows: according to the study hypothesis, echocardiography has better sensitivity and specificity of finding valve pathology, in comparison to basic physical exam using stethoscope. Basic physical exam sensitivity and specificity is approximately 50%. We assume that echocardiography sensitivity and specificity is at least 80%. Under estimation of alpha (two-sided) <0.05 and 80% power, the group of patients with any valve pathology should include 40 patients, with similar group size without valve pathology.

Results
The study included a total of 56 subjects who were examined by the three medical students. The characteristics of the subjects are presented in **Table 1**. Of the total number of subjects, 18 had no valve pathology and 38 had at least one moderate valve pathology, 19 of them having more than one valve malfunction. The following pathologies were identified by echocardiography among the 38 subjects with valve dysfunction: mitral regurgitation (MR): 28 cases (15 mild, 8 moderate, 5 severe); mitral stenosis (MS): 4 cases (2 moderate, 2 severe); aortic regurgitation (AR): 18 cases (10 mild, 7 moderate, 1 severe); aortic stenosis (AS): 10 cases (5 moderate, 5 severe); a total of 60 findings among the 38 subjects with any valve dysfunction. Based on POCUS, students improved their diagnostic sensitivity of the 60 cases of valve dysfunction by 50% without significant change in the specificity (***Table 1***).

3.1 Medical students' skills for diagnosing valvular dysfunction
3.1.1 Mitral valve regurgitation (MR): The students improved their ability to detect 28 cases of MR by 15% when they based their diagnosis on POCUS (from 45% to 60% for physical exam and POCUS, respectively), with concomitant improvement in specificity of 14% (***Table 2***). The accuracy was 69% and 55% for insonation and auscultation, respectively. Even when considering only the cases of moderate and severe MR (13 cases), POCUS demonstrated superiority to auscultation, so that the average ability to identify MR of moderate and severe levels improved by 20% with POCUS (74%) compared to auscultation (54%).

3.1.2 Mitral valve stenosis (MS): 12 exams were performed on 4 subjects with moderate and severe MS. Sensitivity rates rose considerably when students based their diagnosis on insonation (from 8% by auscultation to 92% by POCUS), with only a slight drop in specificity value (95% and 86% for auscultation and POCUS, respectively), with an average kappa value of 0.53 (***Table 2***). The accuracy was 87% and 89% for insonation and auscultation, respectively.

3.1.3 Aortic valve regurgitation (AR): The accuracy of the medical students in diagnosing the 18 cases of AR by auscultation was remarkably poor. By auscultation, students identified 6% of cases of AR and improved by POCUS (31%) with a fall in specificity (95% and 78% for auscultation and POCUS, respectively) (***Table 3***). The accuracy was 63% and 67% for insonation and auscultation, respectively. Students' diagnostic rate by auscultation in the 8 cases of moderate and severe AR was also reported, with a sensitivity of 4% which rose to 39% based on POCUS.

Table 1. Baseline Characteristics of Subjects (n=56).

Variable	Categories		n (%)
Age (mean ± SD)			61.6±13
Gender	Male		35 (62.5)
BMI (mean ± SD)			27.6±4.8
BMI	≤30.0		42 (76.4)
	30.1-35.0		8 (14.5)
	35.1-40.0		5 (9.1)
Pathology	LV systolic dysfunction		17 (30.4)
	Rheumatic injury		5 (8.9)
	Calcified aortic valve		17 (30.4)
	Bi-cuspid aortic valve		0 (0)
	AS	mild	0 (0)
		moderate	5 (8.9)
		severe	5 (8.9)
	AR	mild	10 (17.9)
		moderate	7 (12.5)
		severe	1 (1.8)
	Mitral valve prolapse		1 (1.8)
	MS	mild	0 (0)
		moderate	2 (3.6)
		severe	2 (3.6)
	MR	mild	15 (26.8)
		moderate	8 (14.3)
		severe	5 (8.9)

Legend: AR – Aortic regurgitation, AS – Aortic stenosis, LV – Left ventricle, MR – Mitral regurgitation, MS – Mitral stenosis

3.1.4 Aortic stenosis (AS): Ten subjects had moderate (5 subjects) and severe (5 subjects) AS, which was the pathology that students identified best by auscultation among the 4 valve dysfunctions they investigated (sensitivity 67%, specificity 89%). However, better sensitivity (70%) was demonstrated by POCUS, with only a slight drop in specificity (87%). The accuracy was 82% and 85% for insonation and auscultation, respectively. It should be noted that with the use of POCUS, a wide range of the level of sensitivity among the three students was apparent, seen as well with auscultation (***Table 3***).

3.1.5 Combined valvular dysfunction: More than one pathology was found in 19 subjects (MR + MS = 5, MR + AR = 8, MR + AS = 2, AR + AS = 4). Of the 57 cardiac auscultation examinations on subjects with combined pathology, none was detected by auscultation. On the other hand, 22 such cases were correctly identified by POCUS (39%). Notably, the combined pathologies of the mitral valve (MR + MS) were identified best, so that of 15 examinations, 13 (87%) such cases were correctly identified by POCUS. Of all cases with combined aortic pathology (AS and AR), none was detected by the students by either of the two diagnostic methods.

3.2 Factors that influence more accurate identification of valvular dysfunction by POCUS compared to cardiac auscultation

3.2.1 Related to valve pathology. The ability of the students to correctly identify by POCUS the presence or absence of MR that was missed by auscultation (27%) was clearly superior to the correct identification of MR by auscultation that was missed by POCUS (8%). On the other hand, the ability of auscultation to identify the presence or absence of AR that was missed by POCUS (15%) was slightly superior in comparison to the correct identification by POCUS missed by auscultation (11%). The ability to correctly identify by POCUS the presence or absence of MS and AS that was missed by auscultation (9% and 10%, respectively) was the same as the correct identification of MS and AS by auscultation that was missed by POCUS (9% and 10%, respectively).

3.2.2 Related to the examiner. Variance for arriving at a correct diagnosis by auscultation and POCUS was observed between the three examiners, with a range of 10–18% of cases in which identification by POCUS was more accurate than by auscultation and 5–17% of the cases in which identification by auscultation was more accurate than by POCUS. Among the three examiners, in most cases there was agreement in the assessment between both methods of diagnosis (66–84% of cases).

Table 2. Students' Diagnosis of Mitral Pathology.

	Average				Student 1				Student 2				Student 3			
Parameter	MR (n=28)		MS (n=4)		MR (n=28)		MS (n=4)		MR (n=28)		MS (n=4)		MR (n=28)		MS (n=4)	
	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation
Sensitivity, %	60	45	92	8	64	64	100	25	44	29	75	0	71	43	100	0
Specificity %	79	65	86	95	82	39	77	90	81	89	90	96	75	68	92	98
PPV, %	74	60	45	6	78	51	25	17	71	73	60	0	74	57	50	0
NPV, %	67	54	99	93	70	52	100	94	58	56	98	93	72	54	100	93
Accuracy, %	69	55	87	89	73	52	79	86	62	59	89	89	73	55	93	91
Kappa (p-value)	0.39	0.11	0.53	0.02	0.46 (<0.001)	0.04 -0.783	0.32 -0.001	0.13 -0.338	0.25 -0.049	0.18 0.093)	0.64 (<0.001)	-0.05 -0.69	0.46 -0.001	0.11 -0.408	0.63 (<0.001)	-0.03 -0.78

Legend: MR – Mitral regurgitation, MS – Mitral stenosis, NPV – Negative predictive value, PPV – Positive predictive value
* Kappa values < 0 indicating no agreement, 0–0.20 poor, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good, and 0.81–1 very good agreement

Table 3. Students' Diagnosis of Aortic Pathology

Parameter	Average				Student 1				Student 2				Student 3			
	AR (n=18)		AS (n=10)		AR (n=18)		AS (n=10)		AR (n=18)		AS (n=10)		AR (n=18)		AS (n=10)	
	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation	POCUS	Auscultation
Sensitivity, %	31	6	70	67	33	6	30	60	31	7	100	50	28	6	80	90
Specificity, %	78	95	87	89	58	92	83	80	89	97	93	93	87	97	85	93
PPV, %	44	42	52	59	27	25	27	40	56	50	75	63	50	50	53	75
NPV, %	70	68	93	93	65	67	84	90	75	69	100	90	70	69	95	98
Accuracy, %	63	67	82	85	50	64	73	77	72	68	89	86	68	68	84	93
Kappa (p value)	0.1	0.01	0.49	0.53	-0.08 -0.53	-0.03 -0.751	0.12 -0.363	0.34 -0.009	0.23 -0.069	0.04 -0.582	0.82 (<0.001)	0.47 (<0.001)	0.17 -0.182	0.04 -0.582	0.54 (<0.001)	0.77 (<0.001)

Legend: AR – Aortic regurgitation, AS – Aortic stenosis, NPV – Negative predictive value, PPV – Positive predictive value
* Kappa values < 0 indicating no agreement, 0–0.20 poor, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good, and 0.81–1 very good agreement

3.2.3 Related to the severity of the valve dysfunction. The ability to correctly identify by POCUS the presence of moderate valve dysfunction that was missed by auscultation (38%) was clearly superior to the correct identification of moderate valve dysfunction that was missed by POCUS (2%). Similarly, advantage of POCUS over cardiac auscultation was noted for the cases of severe dysfunction: by POCUS, students correctly identified 34% of severe cases of valve dysfunction lost by auscultation, and auscultation resulted in a correct diagnosis in 13% of severe valve dysfunction missed by POCUS. It should be noted that there is no advantage for POCUS when identifying absence of pathology: 12% superiority of cardiac auscultation compared to 7% superiority with POCUS.

3.2.4 Univariate and multivariate analysis: In a univariate analysis POCUS testing demonstrates superiority in the accurate identification of MR as opposed to AS (presence or absence of pathology) vs. auscultation (OR 2.78, 95% CI 1.56–4.95, p = 0.001). However, in a multivariate analysis (***Table 4***) there was no statistical superiority of POCUS to cardiac auscultation for a more accurate identification (presence or absence) for any sub-group of valve pathology. The previous model was further adjusted for BMI and age. It is apparent that superiority exists for POCUS in females compared to males (OR 1.56, 95% CI 1.04–2.32, p = 0.030). In addition, POCUS has superiority in identifying presence of valvular dysfunction of all levels of severity compared to accurate identification of the absence of malfunction (for mild pathology: p = 0.009, OR 2.76; for moderate pathology: p <0.001, OR 6.73; for severe pathology: p = 0.001, OR 4.15).

Table 4. Multivariate Analysis (Ordinal Generalized Estimating Equation) for Accurate Diagnosis by POCUS (Pathology or Normal Valve) vs. Physical Exam.

p value	95% CI	OR	Variable	
0.295	0.97-1.01	0.99	Age	
0.795	0.96-1.04	0.99	BMI	
0.03	1.04-2.32	1.56	Gender (with male as reference group)	
0.217	0.47-1.19	0.75	AR	Pathology sub-type (with AS as reference group)
0.222	0.79-2.76	1.48	MR	
0.52	0.73-1.86	1.17	MS	
0.009	1.29-5.91	2.76	mild	Pathology severity (with no pathology as reference group)
<0.001	3.62-12.53	6.73	moderate	
0.001	1.83-9.43	4.15	severe	

Legend: AR – Aortic regurgitation, AS – Aortic stenosis, BMI – Body mass index, MR – Mitral regurgitation, MS – Mitral stenosis
*Outcome defined as ordinal variable: +1 if POCUS superior to physical exam, 0 if POCUS = physical exam, and -1 if POCUS inferior to physical exam.

Discussion

Our study demonstrates that when students based their diagnosis of valve dysfunction on cardiac auscultation, their performance was poor (mean sensitivity 32%, mean specificity 86%), particularly for identifying valve pathologies that cause a diastolic murmur (mean sensitivity 7%, mean specificity 95%). Students noticeably improved their diagnostic ability with the use of POCUS (mean sensitivity 64%, mean specificity 83%). However, the accuracy rate remains unchanged between auscultation-based and insonation-based diagnosis of the left-side valve lesions, except for MR in which insonation has better sensitivity, specificity, and accuracy than auscultation. It is obvious that auscultation's specificity can be outstanding if the sensitivity of the method is so low. These data on the diagnostic rate of cardiac auscultation are similar to the results of historical studies that exist in the field, and have not improved for the last two decades, despite the fact that the innovative methods based on high quality audio and self-study techniques are widely available.[1-3] In a multicenter study, Vukanovic-Criley et al. showed that physicians not only do not improve their cardiac physical examination after graduation from medical school but probably even show a decline in this skill.[12] Hence, our students were in the best position to succeed with cardiac auscultation.

A serious concern which arises from our study as well as from a study by Stokke et al. is that even when testing only moderate or severe valve dysfunction, students' diagnoses were poor when relying on cardiac auscultation (mean sensitivity 35%) and improved considerably using POCUS (mean sensitivity 70%).[13] POCUS showed remarkable advantage over auscultation for identifying valve regurgitations, especially MR and AR. When considering only the moderate and severe cases of MR there was a 34% improvement in sensitivity between "sound"-based and "ultrasound"-based diagnosis, as well as in the specificity. The advantage of using POCUS is stronger in an isolated analysis of moderate and severe levels of AR, which shows an improvement of 97% in sensitivity in examination with POCUS vs. cardiac auscultation, but the specificity falls considerably when based on POCUS; therefore, the accuracy remained unchanged. Both, MR and AR are diagnosed by color Doppler, available in the portable device used by our students. The regurgitant jet of MR that empties into the large cavity of the left atrium is much more visible than the AR jet that goes back into a small cavity like the left ventricular outflow tract. This fact may explain, at least partially, the different accuracies of the students by insonation for diagnosing MR and AR. This problem probably could be solved by a longer period of training in POCUS.

In addition, an apparent advantage of the use of POCUS over cardiac auscultation is the ability of POCUS to detect several existing pathologies simultaneously. None of the cases with multiple pathologies were detected by auscultation by any of the examiners. In contrast, with the use of POCUS, 39% of the cases with multiple pathologies were identified. This capability is even more pronounced in the identification of mitral valve pathologies, in which 87% of the cases of multiple pathologies were identified by POCUS.

The improved ability of the students to correctly recognize valve pathology by POCUS was dependent on several parameters. First, we found variation according to pathology type: the improved diagnosis with POCUS was remarkable for MR, whereas for AS and MS there was no improvement. The pocket device used in our study lacked spectral Doppler, which made it impossible to measure flow velocities, making the identification of valve stenosis challenging. It is possible that the ability to diagnose MS and AS would be further enhanced by the presence of an echo device with spectral Doppler capability. Improvements and rapid advances in technology are evolving which will aid in bridging this technical gap and spectral Doppler capability is already included in new pocket ultrasound devices. Second, POCUS was significantly superior to cardiac auscultation for pathology recognition, in any severity, but inferior for correctly diagnosing the presence of normal valve. The non-superiority of POCUS over auscultation in the correct diagnosis of normal valve function may be affected by the very low sensitivity of auscultation to identify valve pathology. It is also probable that our students were committed to finding cardiac pathology using the new diagnostic method, which could have impacted on their relatively low specificity over auscultation to identify normal valves.
Finally, we found significant variability among the three students in their diagnostic accuracy for both diagnostic modalities, probably due to different personal learning curves. Even though in most cases correct identification of the presence or absence of valve pathology was done by POCUS and auscultation, it was observed that there were more cases correctly diagnosed only by POCUS than cases correctly diagnosed by auscultation only. Our students received eight hours more of training than Stokke's students (four hours training), however the results were similar between studies.[13] It is likely that the number of hours that the students spent on training was the same because Stokke students were encouraged to participate in a pre-course online training that included normal and pathologic echocardiography studies, as well as main cardiac ultrasound views and maneuvers to obtain the images.[13] The ultrasound training that the students received was short when compared to lessons on cardiac auscultation, and their experience using ultrasound for diagnosis was significantly less than their three years of experience using a stethoscope. In other words, it seems that the learning curve of ultrasound is shorter than that of cardiac auscultation. Implementation of ultrasound techniques in the curriculum of medical students in pre-clinical years may improve their diagnostic capability based on ultrasound in the near future.[14] In our medical school curriculum, POCUS education is integrated along the clinical years. The students are being tested on their performance of cardiac ultrasound, as well as on lung, vascular, and the focused assessment with sonography for trauma (FAST) exam. They are also tested during their clinical years on their physical examination, including cardiac auscultation. We believe that POCUS can be used as an instrument to improve auscultatory skills by providing immediate confirmation or rejection of the auscultatory findings. This feedback is essential for the learning process.

The main barriers of incorporating POCUS into the medical school curriculum include time that is added into the demanding curriculum for a new course, the necessity of sufficient instructors to teach a growing number of students in small groups, and financial issues related to the cost of the ultrasound devices and cost of the instructions' teaching time.[14] Our experience has demonstrated that some of these limitations can be overcome by incorporating students as instructors of their classmates and students' self-learning by web-based POCUS modules.[16, 17] There are unresolved issues of ultrasound education in medical schools, such as duration of the instruction and knowledge retention at the final year of the medical school.[18, 19] The introduction of ultrasound in the preclinical years, its teaching in clinical courses and clinical rotations, and testing in practical exams could reinforce further knowledge retention.

A major limitation of this study is the small operator sample size, including only three medical students that conducted the POCUS examination and the auscultation. Although they examined only 56 patients, different valve pathologies were examined in each patient (aortic valve stenosis and regurgitation, mitral valves stenosis and regurgitation) with a total of 60 pathologies that were found among 38 patients. The students were not picked by their performance or by their grades but rather arbitrarily. The results we present should be considered in the context of pilot study results, and larger studies should be conducted to confirm the results of this study. Another limitation relates to the imaging quality of POCUS examination that was not graded. However, none of the recruited subjects were discarded from the analysis due to poor POCUS imaging. Finally, the three students in the study were recruited based on their willingness to participate in a research project; we did not assess their diagnostic skills prior. They received the same instructions, and we cannot explain the differences in students' results, other than by differing amounts of time spent by each of them on self-practice.

Conclusions

Final year medical students' cardiac auscultation skill for the detection of moderate and severe valvular dysfunction is poor. A concise cardiac ultrasound training allows medical students to improve their valvular pathology diagnostic capability significantly. POCUS is also significantly better in the diagnosis of a combination of valve malfunctions in the same patient when compared to auscultation. The results we present should be considered in the context of pilot study results, and larger studies should be conducted to confirm the results of this study.

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Conceptualization: LZ, TM, TS, YF, LB, NLC, SLK; Data Curation: TM, TS; Formal Analysis: TM, TS, LB, NLC, SLK; Investigation: LF, TM, TS, YF, LB, SLK; Methodology: TM, TS; Project Administration: LZ, LB; Resources: TM, TS, LB; Supervision: LZ, LF, SLK; Validation: TM, TS; Visualization: LZ, LF, TM, SLK; Writing – Original Draft Preparation: LF, TS, YF, NCL, SLK; Writing – Review & Editing: LZ, LF, TM, TS, YF, LB, NLC, SLK.

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