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BRIEF REPORT

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Focused training for goal-oriented hand-held echocardiography performed by noncardiologist residents in the intensive care unit

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Abstract *Objective:* We sought to evaluate the efficacy of a limited training dedicated to residents without knowledge in ultrasound for performing goal-oriented echocardiography in ICU patients. *Design:* Prospective pilot observational study. *Setting:* Medical-surgical ICU of a teaching hospital. *Patients:* 61 consecutive adult ICU patients (SAPS II score: 38 ± 17; 46 ventilated patients) requiring a transthoracic echocardiography were studied. *Interventions:* After a curriculum including a 3-h training course and 5 h of hands-on training, one of four noncardiologist residents and an intensivist experienced in ultrasound subsequently performed hand-held echocardiography (HHE), independently and in random order. Assessable "rule in, rule out" clinical questions were purposely limited to easily identifiable conditions by the sole use of two-dimensional imaging. *Measurements and results:* When compared with residents, the experienced intensivist performed shorter examinations (4 ± 1 vs. 11 ± 4 min: $p < 0.0001$) and had significantly less unsolved clinical questions [3 (0.8%) vs. 27 (7.4%) of 366 clinical questions: $p < 0.0001$]. When addressed, clinical questions were adequately appraised by residents: left ventricular systolic dysfunction [Kappa: 0.76 ± 0.09 (95% CI: 0.59–0.93)], left ventricular dilatation [Kappa: 0.66 ± 0.12 (95% CI: 0.43–0.90)], right ventricular dilatation [Kappa: 0.71 ± 0.12 (95% CI: 0.46–0.95)], pericardial effusion [Kappa: 0.68 ± 0.18 (95 CI: 0.33–1.03)], and pleural effusion [Kappa: 0.71 ± 0.09 (95% CI: 0.53–0.88)]. The only case of tamponade was accurately diagnosed by the resident. *Conclusions:* Limited training of noncardiologist ICU residents without previous knowledge in ultrasound appears feasible and efficient to address simple clinical questions using point-of-care echography. Influence of the learning curve on diagnostic accuracy and potential therapeutic impact remain to be determined.

Keywords Transthoracic echocardiography · Two-dimensional echocardiography · Curriculum · Intensive care

Introduction

Echocardiography constitutes an unparalleled imaging modality that provides structural and functional information on the heart and great vessels at patient bedside. Ease of use, portability, and accuracy account for the diffusion of this diagnostic tool in intensive care units (ICUs) [1]. Continuous progress in electronics allowed the recent emergence of small, battery-operated, low-cost, and highly portable devices. Hand-held echocardiography (HHE) has been recently validated in the ICU for simple diagnoses based on two-dimensional imaging [2, 3].

Leading academic teams in cardiology have recently reported their successful experience in developing focused training in echocardiography for medical residents without previous experience in ultrasound [4], but this approach has yet been scarcely evaluated in adult ICU patients [5]. Accordingly, we sought to evaluate the efficacy of a limited training dedicated to residents without previous knowledge in ultrasound for performing goal-oriented echocardiography in critically ill patients using a hand-held system.

Materials and methods

This study was approved by our regional Ethics Committee that waived the need for informed consent.

Focused training

Under the supervision of an experienced intensivist with level-III competence in echocardiography [6], four non-cardiologist residents (anesthesiologists, $n = 2$; internal medicine, $n = 2$) without previous experience in ultrasound underwent a 3-h training course and 5 h of hands-on training. This focused training was adapted from a previously validated curriculum [7]. The number of assessable clinical questions was purposely limited to easily identifiable conditions by the sole use of two-dimensional imaging (Table 1). Courses were focused on the description of standard echocardiographic views and normal anatomy, and on the identification of gross pathologic changes (e. g., dilated hypokinetic left ventricle, dilated right ventricle, pericardial effusion and tamponade, pleural effusion) using digital loops. Hands-on sessions were performed on sedated patients under ventilator (10–12 examinations per resident) and particular attention was directed toward: (a) obtaining adequate windows and proper orientation in the subcostal, apical four-chamber, and parasternal long and short axis views; (b) identifying correctly anatomic landmarks in corresponding echocardiographic views; and (c) diagnosing accurately all pathologic features covered during courses.

Patients

After completion of the focused training and during a 2-month period, all patients who required a transthoracic echocardiography were examined subsequently by one of the residents and by same trained level-III intensivist, in random order depending on respective availability, but within a 1-h time frame. Indication for echocardiography was left to the discretion of the attending physician, according to standard care in our ICU. In each patient, operators attempted to answer the following "rule in, rule out" clinical questions: presence of a left ventricular (LV) systolic dysfunction (eye-ball evaluated ejection fraction $\leq 50\%$), LV dilatation, right ventricular (RV) dilatation (cor pulmonale), uncomplicated pericardial effusion or tamponade, and presence of pleural effusion. In case of undetermined interpretation due to suboptimal imaging quality (i. e., absence of clear visualization of all anatomical structures), the corresponding clinical question was considered not addressed. Both the residents and experienced intensivist had access to the same information regarding the medical history and clinical status of patients but performed HHE and fulfilled the case report forms independently.

Table 1 Curriculum for goal-oriented hand-held echocardiography in ICU patients

Curriculum for noncardiologic residents (two-dimensional imaging)
Didactics (3 h) – Ultrasound basics – Overview on the use of echocardiography in the ICU settings – Advantages and limits of hand-held echocardiography – Standard windows to the heart: subcostal, apical four-chamber, parasternal views. Cardiac anatomy: chambers; valves; pericardium; great vessels – Left ventricular systolic function (global): normal and case reviews – Left ventricular cavity enlargement: echocardiographic features – Right ventricular dilatation: definition; etiology; echocardiographic features – Pericardial fluid: etiology; echocardiographic features; tamponade – Pleural fluid effusion: echocardiographic features; measurement of interpleural distance for semi-quantitative evaluation [a]
Hands-on (5 h) – Hand-held device: operating and setting information – 10–12 ventilated ICU patients to cover all above-listed pathologic features – Standard windows to the heart: subcostal; apical four-chamber, parasternal views – Measurement [a]: maximal interpleural distance

[a] Two-dimensional measurement using electronic calipers incorporated in the portable device

Point-of-care echocardiography

Examinations were performed using a hand-held device with two-dimensional capability (Optigo, Philips, France). Color Doppler mapping was purposely not used. Each patient was systematically screened for the four studied echocardiographic windows. The number of acoustic windows obtained was recorded and global imaging quality was graded as follows: 0, no image; 1, poor imaging quality (identification of $< 50\%$ of left endocardial borders); 2, good imaging quality (identification of $> 50\%$ of LV endocardial borders); 3, excellent imaging quality (identification of the entire LV endocardial borders). In the presence of a pleural effusion, the maximal interpleural distance was measured, as previously described [8]. Values greater than 45 mm and 50 mm for right- and left-sided effusions, respectively, were indicative for large pleural effusions [8]. Since the Optigo system does not allow video or digital loop recording, interpretation of HHE and two-dimensional measurements were performed on-line by operators at bedside. The time required to perform the examination was noted.

Statistics

The number of acoustic windows and proportion of addressed questions were compared between residents and the experienced intensivist using the MacNemar test. Imaging quality graded by these operators and duration of HHE study were compared using a Wilcoxon test. Agreement between responses to clinical questions provided by the residents and the experienced intensivist was assessed using the Cohen's Kappa coefficient [9]. Agreement between echocardiographic measurements performed by investigators was assessed by the intraclass correlation coefficient [10]. In both cases, 95% confidence intervals (95% CI) were also calculated.

Results

Sixty-one patients underwent a point-of-care examination [age (mean ± SD): 64 ± 14 years; SAPS II score: 38 ± 17; 46 ventilated patients]. Patients were admitted to the ICU for a medical condition ($n = 51$), complicated surgery ($n = 7$), or a multisystem trauma ($n = 3$). Residents performed a mean of 15 HHE studies (range: 11–20). When compared with residents, the experienced intensivist performed shorter examinations (4 ± 1 vs. 11 ± 4 min: $p < 0.0001$) with more acoustic windows (200 vs. 221 of 244 potential windows: $p = 0.0018$) and better imaging quality (mean grade, 1.95 ± 0.76 vs. 1.75 ± 0.66: $p < 0.0001$). The trained intensivist had significantly less unaddressed clinical questions than residents [3 (0.8%) vs. 27 (7.4%) of 366 clinical questions: $p < 0.0001$].

When addressed, clinical questions were adequately appraised by residents as reflected by the agreement of their qualitative diagnoses with those of the experienced intensivist (Table 2). Residents assessed inadequately LV systolic function in 7 of 58 patients (12%). In all discrepant cases, LV systolic function was considered moderately depressed instead of normal by either the resident or the experienced intensivist. The RV dilatation was not accurately identified by residents in 5 of 56 patients (9%). A single resident accounted for three of the four discrepant negative results. Pericardial effusions were correctly diagnosed by residents (Table 2). The two discrepant positive results were attributable to the presence of fat along the free wall of the RV in the subcostal view which was erroneously interpreted as a mild pericardial effusion, whereas a trivial effusion without clinical relevance was only identified by the experienced intensivist in a hemodynamically stable patient. The only case of tamponade encountered in this study was accurately diagnosed by the resident. Similarly, residents correctly diagnosed pleural effusions using pleural ultrasonography (Table 2) and adequately identified large volumes of effu-

Table 2 Clinical questions addressed using hand-held echocardiography; *LV* left ventricle; *RV* right ventricle

Clinical questions	Cases identified by the experienced intensivist (*n*)	Questions not addressed by residents/ experienced intensivist (*n*) [a]	Discrepant positive results yielded by residents (*n*) [b]	Discrepant negative results yielded by residents (*n*) [b]	Kappa values for all addressed clinical questions [c]
LV systolic dysfunction	26 (43%)	3/0	4	3	0.76 ± 0.09 (0.59-0.93)
LV dilatation	13 (21%)	4/0	4	3	0.66 ± 0.12 (0.43-0.90)
RV dilatation	13 (21%)	5/1	1	4	0.71 ± 0.12 (0.46-0.95)
Pericardial effusion	6 (10%)	2/1	2	1	0.68 ± 0.18 (0.33-1.03)
Tamponade	1 (2%)	–	0	0	–
Pleural effusion	43 (70%)	13/1	2	1	0.71 ± 0.09 (0.53-0.88)

[a] Due to inadequate imaging quality or undetermined interpretation; [b] When compared with the interpretation of the experienced intensivist; [c] Numbers in parentheses are 95% confidence intervals

sion [Kappa: 0.67 ± 0.18 (95% CI: 0.33–1.02)]. Intraclass correlation coefficient was 0.89 (95% CI: 0.67–0.97) and 0.81 (95% CI: 0.60–0.92) for the measurement of left and right maximal interpleural distances, respectively.

Discussion

The present pilot study shows that an 8-h focused training program allowed noncardiologist residents to efficiently use HHE for the identification of gross cardiac changes and pleural effusions. In the current study, eye-ball identification of global LV systolic dysfunction by residents was fairly accurate, as previously reported in adult patients [11–15] and in pediatric patients [16, 17]. In keeping with previous results [17], a focused training program allowed the identification of dilated LV cavity by residents in our ICU patients. Similarly, residents adequately identified the presence of a RV dilatation, as recently shown when using transesophageal echocardiography by novice intensivists [18]. As previously reported [14, 17], residents correctly identified the presence of pericardial effusion and the single case of tamponade diagnosed in the present study. In the specific setting of patients sustaining life-threatening tamponade, HHE appears ideally suited for prompt recognition and to guide rapid pericardiocentesis [19]. In the present study, residents identified satisfactorily the presence of large pleural effusion [8], as reflected by fairly high intraclass coefficient correlations for the measurement of interpleural distance.

The training curriculum proposed to medical residents without previous experience in ultrasound for goal-oriented point-of-care echocardiography varied widely among studies [4]. The beneficial effect of a tailored training program on the diagnostic accuracy of HHE users has been documented [7, 15]. With a mean of 15 HHE examinations performed in the current study, the residents were presumably on the ascending part of their learning curve. Accordingly, improvement of the promising results reported in this pilot study is anticipated with accumulated experience by noncardiologist residents. Importantly, the present results cannot be extended to other indications of echocardiography (e. g., evaluation of complex shock) which require a higher level of training [20] and frequently a transesophageal examination [1].

The present study has several limitations. Firstly, the relatively low number of enrolled patients and participating trainees did not allow for evaluating the effect of the learning curve on individual diagnostic accuracy among trained residents. Secondly, two-dimensional measurements of ventricular end-diastolic diameters were not performed to help operators to more objectively identify left or right ventricular dilatation. Thirdly, the potential impact of point-of-care echocardiography on therapy was not evaluated. Fourthly, we used HHE with no spectral Doppler capability and limited setting possibilities (depth of image and gain) to facilitate ultrasound instrument settings. Nevertheless, the present data can presumably be extended to two-dimensional imaging obtained by conventional equipment.

Conclusion

In the ICU environment, limited training of noncardiologist residents without previous knowledge in ultrasound appears feasible and efficient to address simple limited clinical questions using point-of-care echography. The influence of the learning curve on diagnostic accuracy and the potential therapeutic impact of focused echocardiography performed by noncardiologist residents remain to be determined by further studies.

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