



Comparison of qualitative information obtained with the echocardiographic assessment using subcostal-only view and focused transthoracic echocardiography examinations: a prospective observational study

Comparaison des informations qualitatives obtenues par évaluation échocardiographique à l'aide d'une unique vue sous-costale et d'examens ciblés d'échocardiographie transthoracique : une étude observationnelle prospective

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Abstract

Purpose To evaluate whether echocardiographic assessment using the subcostal-only window (EASy) compared with focused transthoracic echocardiography (FTTE) using three windows (parasternal, apical, and subcostal) can provide critical information to serve as an entry-point technique for novice sonographers.

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Methods We conducted a retrospective study to compare diagnostic information acquired during EASy and FTTE examinations on qualitative left ventricular (LV) size, LV contractility, right ventricular (RV) size, RV contractility, interventricular septal position, and the presence of a significant pericardial effusion. Anesthesiology residents (novice users) performed FTTE for hemodynamic instability and/or respiratory distress or to define volume status in the perioperative setting, and later collected images were grouped into EASy and FTTE examinations. Both examinations were reviewed independently by a board-certified cardiologist and an anesthesiologist

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proficient in critical care echocardiography. FTTE and EASy findings were compared utilizing Gwet's ACI coefficient to consider disagreement due to chance.

Results We reviewed 102 patients who received FTTE over a period of 14 months. Of those, 82 had usable subcostal views and were included in the analysis. There was substantial agreement for qualitatively evaluating RV size (Gwet's ACI, 0.70; 95% confidence interval [CI], 0.54 to 0.85), LV size (Gwet's ACI, 0.73; 95% CI, 0.58 to 0.88), and LV contractility (Gwet's ACI, 0.73; 95% CI, 0.58 to 0.88) utilizing EASy and FTTE. Additionally, there was an almost perfect agreement when assessing the presence of pericardial effusion (Gwet's ACI, 0.98; 95% CI, 0.95 to 1.0) and RV contractility (Gwet's ACI, 0.84; 95% CI, 0.74 to 0.95) and evaluating the motion of the interventricular septum (Gwet's ACI, 0.92; 95% CI, 0.85 to 0.99).

Conclusions When images could be obtained from the subcostal window (the EASy examination), qualitative diagnostic information was sufficiently accurate compared with information obtained during FTTE examination. Our findings suggest that the EASy examination can serve as the entry point technique to FTTE for novice clinicians.

Résumé

Objectif Déterminer si l'évaluation échocardiographique se fondant sur la fenêtre unique sous-costale (EASy) par rapport à une échocardiographie transthoracique ciblée (ETTC) fondée sur trois fenêtres (parasternale, apicale et sous-costale) pouvait fournir des informations critiques et servir de technique de départ pour enseigner l'échographie aux novices.

Méthode Nous avons réalisé une étude rétrospective afin de comparer les informations diagnostiques acquises lors des examens échocardiographiques EASy et ETTC concernant la taille qualitative du ventricule gauche (VG), la contractilité du VG, la taille du ventricule droit (VD), la contractilité du VD, la position septale interventriculaire et la présence d'un épanchement péricardique significatif. Les résidents en anesthésiologie (utilisateurs novices) ont réalisé une ETTC pour détecter une instabilité hémodynamique et / ou une détresse respiratoire ou pour définir l'état volémique dans un contexte périopératoire; par la suite les images colligées ont été regroupées en examens EASy et ETTC. Les deux examens ont été indépendamment passés en revue par un cardiologue certifié et un anesthésiologiste formé en échocardiographie de soins intensifs. Les résultats des examens d'ETTC et d'EASy ont été comparés en utilisant le coefficient ACI de Gwet pour tenir compte des désaccords dus au hasard.

Résultats Nous avons passé en revue 102 patients ayant reçu une ETTC sur une période de 14 mois. De ce nombre,

82 ont présenté des vues sous-costales utilisables qui ont été incluses dans l'analyse. Il y avait une importante concordance entre les examens EASy et ETTC pour évaluer qualitativement la taille du VD (ACI de Gwet, 0,70; intervalle de confiance [IC] à 95 %, 0,54 à 0,85), la taille du VG (ACI de Gwet, 0,73; IC 95 %, 0,58 à 0,88) et la contractilité du VG (ACI de Gwet, 0,73; IC 95 %, 0,58 à 0,88). De plus, il y avait une concordance quasi parfaite lors de l'évaluation de la présence d'épanchement péricardique (ACI de Gwet, 0,98; IC 95 %, 0,95 à 1,0) et de la contractilité du VD (ACI de Gwet, 0,84; IC 95 %, 0,74 à 0,95) et de l'évaluation du mouvement du septum interventriculaire (ACI de Gwet, 0,92; IC 95 %, 0,85 à 0,99).

Conclusion Lorsque les images pouvaient être obtenues à partir de la fenêtre sous-costale (examen EASy), les informations diagnostiques qualitatives étaient suffisamment précises par rapport aux informations obtenues lors de l'examen d'ETTC. Nos résultats suggèrent que l'examen EASy peut servir de technique d'apprentissage précédant l'ETTC pour les cliniciens novices.

Keywords Echocardiography · Point-of-care ultrasound · Hemodynamic instability · Perioperative assessment · Anesthesiology training

Point-of-care ultrasound (POCUS) is commonly used in acute care settings.¹⁻⁵ Emergency medicine physicians, intensivists, hospitalists, and anesthesiologists are using POCUS to address rapid changes in a patient's hemodynamic and/or respiratory status caused by pathologic process such as cardiac tamponade, hypovolemia, and acute ventricular systolic dysfunction.⁶⁻¹⁰

Focused transthoracic echocardiography (FTTE) is an application of POCUS, which evolved from comprehensive transthoracic echocardiography for urgent assessment of cardiopulmonary status.³ The FTTE examination typically comprises three windows that are identified based on the position of the ultrasound probe: parasternal, apical, and subcostal (Fig. 1).¹¹ While primarily focusing on the heart, imaging the inferior vena cava (IVC) can also be performed from the subcostal window and provides important information during hemodynamic assessment. Cumulatively, the images obtained during FTTE can provide a rapid, qualitative, or semi-quantitative assessment of ventricular systolic function, myocardial wall motion abnormalities, gross valvular disease, pericardial effusion, volume status, and real-time fluid responsiveness.¹¹ This technique is also useful as a timely

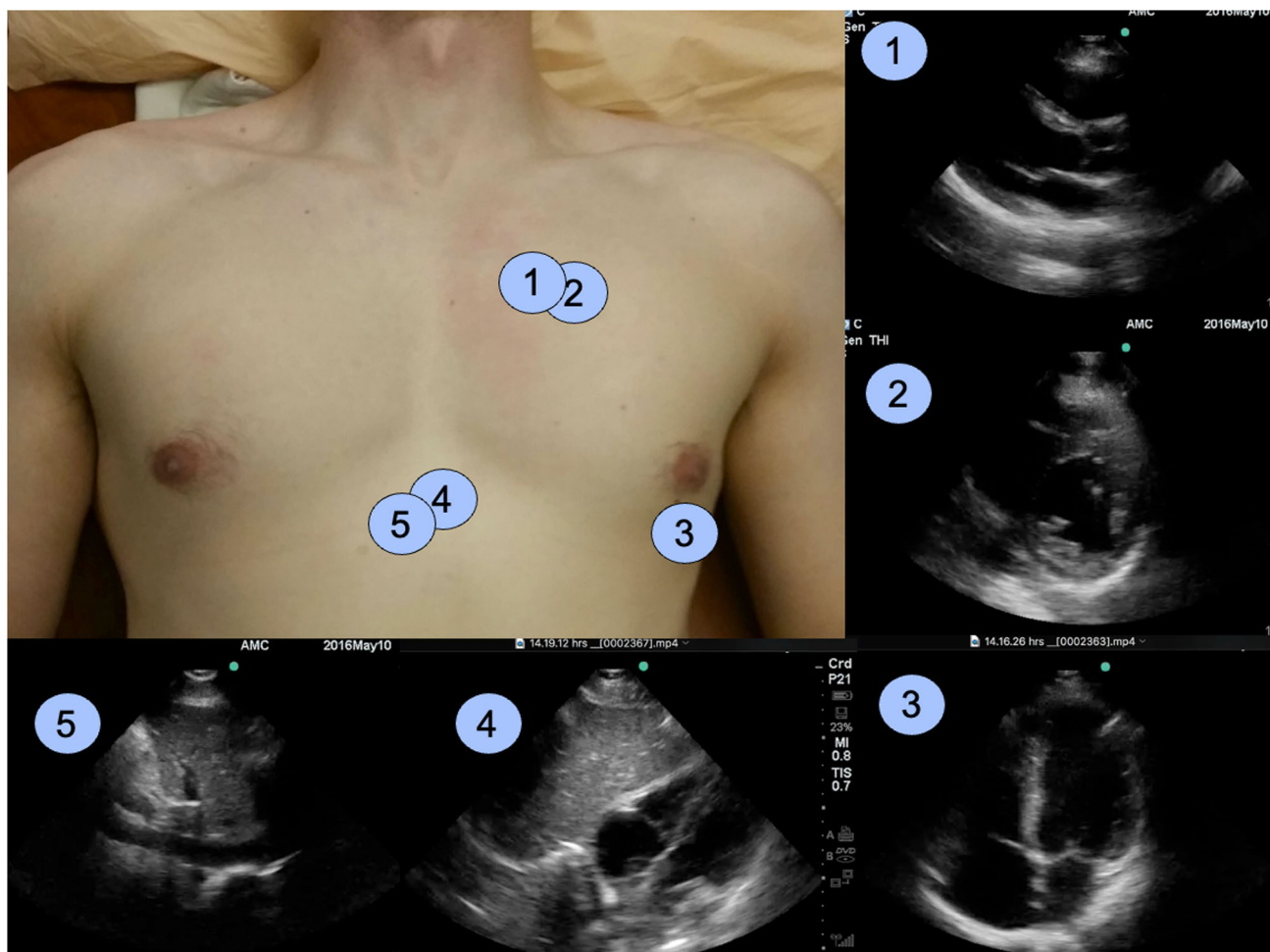


Fig. 1 FTTE includes five views obtained from three windows: (1) parasternal long axis, (2) parasternal short axis, (3) apical four chamber, (4) subcostal long access, (5) aubcostal IVC.

preoperative tool that can determine relevant information regarding the qualitative cardiac performance and has been shown to impact patient morbidity and mortality.^{8,12}

The most common limiting factor for widespread use of FTTE remains the lack of expertise among clinicians; nevertheless, limited resources can also serve as a substantial barrier.¹³ While efforts have been made to investigate the most engaging and effective way to introduce FTTE to providers,¹⁴ adequate competence in this field became a core requirement in several specialties and remains an area of great interest.¹⁵

When patients are hemodynamically unstable and time constraints prohibit a comprehensive examination, obtaining just one view of the heart and IVC may prove to be a viable, time-saving approach (Electronic Supplementary Material [ESM], eVideo).^{16–18} In case series of patients with penetrating anterior chest trauma, the cardiac component of FAST examination (which includes the single subcostal cardiac view examination) was valuable in determination of traumatic pericardial

effusion and effectively guided emergent surgical decision-making.¹⁹ In recent published case series, we demonstrated the feasibility of resident-performed EASy in advanced life support (EASy-ALS) and in the peri-resuscitative period.¹⁸ Consistent with previously reported protocols,^{16,17} we observed that teaching EASy-ALS simplifies the training by focusing on just one window during evaluation of patients with hemodynamic instability.¹⁸

While we previously demonstrated that findings of ventricular function, volume status, and pericardial effusion were consistent in 96% of patients with interpretable EASy images when immediately compared with FTTE by the supervised novice residents performing both examinations, such study design is prone to biased estimates.²⁰ We designed the current study to compare diagnostic information acquired during EASy and FTTE examinations in the perioperative setting when images were independently interpreted by experts.

Methods

Patient population

The Institutional Review Board (IRB) of Albany Medical Center approved this retrospective study. The requirement for written informed consent was waived by the IRB. We reviewed charts of all patients who received FTTE by anesthesiology residents. We included studies performed on perioperative patients over the age of 18 yr, located in the operating room, post-anesthesia care unit (PACU), and surgical intensive care unit, for whom both FTTE images and interpretation were available. Patients undergoing cardiac surgery were excluded. Indications for FTTE included: 1) hemodynamic instability defined by either hypotension with mean arterial blood pressure < 65 mm Hg or shock requiring vasoactive medications; 2) volume assessment for patients with oliguria defined by urine output < 0.5 mL·kg⁻¹·hr⁻¹; 3) respiratory failure defined by acute decrease in oxygen saturation to < 90%; 4) preoperative FTTE evaluation of American Society of Anesthesiologists functional class III and IV patients scheduled for major vascular and abdominal procedures upon request by attending anesthesiologist.

Training requirements

All residents completed a four-day course in FTTE and EASy during their postgraduate year 3. The course was taken during PACU rotation and consisted of didactic lectures, hands-on training, and simulation. Didactic prerecorded lectures were provided through licensed web-based course by the Society of Critical Care Medicine. These lectures were moderated by faculty member, went over ultrasound physics and clinical applications, and were delivered during four-hour daily sessions over four days. Hands-on training included completion of 20 FTTE studies. Finally, all residents participated in four-hour-long high-fidelity team-based simulation training encompassing five pulseless electrical activity arrest scenarios: hypovolemia, massive myocardial infarction, massive pulmonary embolism, tamponade, and tension pneumothorax. Upon completion of training and achieving competency, residents were signed-off to perform EASy and FTTE without direct supervision but with mandatory review of each case.¹⁸

Data collection

Anesthesiology residents obtained the subcostal views first (EASy examination of the heart and IVC), followed by the apical and parasternal views to complete the FTTE. All images were obtained using an ultrasound machine (X-

Porte, FUJIFILM Sonosite, Inc., Bothell, WA, USA) equipped with a phased array transducer. Studies were interpreted by the resident directly supervised by a faculty member who was considered proficient in critical care ultrasound (i.e., had taken and passed the National Board of Echocardiography special competencies in critical care echocardiography examination in January 2019 and who used POCUS on a regular basis in the intensive care unit). Findings relevant to clinical care were shared in real-time with the patient's primary medical team. The entire examination was saved as FTTE examination and de-identified for the purpose of later review. Next, subcostal images of the heart and IVC were copied and saved in a separate file to represent EASy examination. At a later date, EASy and FTTE examinations were independently reviewed by a cardiologist (J.S.M.) certified in advanced echocardiography by N.B.E. and a critical care board-certified anesthesiologist considered proficient in critical care ultrasound (N.B.). J.S.M. reviewed images from the EASy examination for the first 50 patients and images from the FTTE examination for the last 52 patients, while N.B. reviewed images from the FTTE examination for the first 50 patients and images from the EASy examination for the last 52 patients.

To evaluate quality of studies, we used a scoring system by assigning 0–2 points for each one of the six components of examination (pericardium, right ventricular [RV] size, RV function, interventricular septum, left ventricular [LV] size, and LV function) based on confidence of evaluator in observed findings. Zero points were assigned if evaluator was unable to assess the component of the examination; one point was assigned if there was incomplete view and additional views would be required for evaluation, and two points were assigned if there was complete view of the structure. Based on the total score the examination was graded as good (score 10–12), adequate (score 7–9), or poor (score 6 and below). Studies where subcostal views were of poor quality or documented as “unobtainable” were excluded from the analyses; nevertheless, the rest of the examination was completed and saved for further review.

During their review, J.S.M. and N.B. documented whether 1) a significant pericardial effusion was present (defined by a linear two-dimensional measurement of > 10 mm present throughout the cardiac cycle); 2) the right and left ventricles were of normal dimension or enlarged using visual estimation; 3) the RV and LV systolic functions were subjectively normal or depressed; 4) the interventricular septum bowed to the left any time throughout the cardiac cycle as a sign of RV strain. Reviewers used the same interpretation form and taxonomy (ESM eAppendix). For the purpose of this study, all findings for each indication were classified on a binary

scale (normal vs abnormal); the normal category included small and hyperdynamic ventricles. Discrepancies then were further examined to determine whether pathology missed was actionable enough to intervene.

Statistical analysis

After the review process, findings between EASy and FTTE were analyzed with Gwet's AC₁ coefficient to consider disagreement due to chance. Corresponding 95% confidence intervals were estimated by using the "gac" function from the "rel" package (with R software). Agreement measures range from 0 to 1 where coefficients ≤ 0.2 are indicative of slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and ≥ 0.80 almost perfect agreement according to benchmark scale originally provided for Cohen's kappa interpretation.²¹ Categorical variables were summarized with frequencies and percentages. Continuous variables were reported as mean (standard deviation) or median (interquartile range), as appropriate. All tests were two-sided, and *P* values < 0.05 were considered statistically significant. All analysis was performed in R Statistical Software (version 3.6.1; R Foundation for Statistical Computing, Vienna, Austria).

Results

All reviewed images were acquired by eight anesthesia residents (5–19 examinations per each resident), and we identified 102 patients who received FTTE from August 2017 to September 2018. The average time spent to acquire EASy was 4 min, and FTTE was 16 min. Image quality is described in Fig. 2. Twenty studies were excluded from the two experts' comparison because they were reported with a "poor" or "unobtainable" subcostal image. The two most common indications for examination were preoperative assessment and arterial hypotension (Table 1).

When reviewing the acquired images of the remaining 82 patients, the two independent reviewers displayed substantial overall agreement on the assessment of RV size (Gwet's AC₁, 0.70; 95% confidence interval [CI], 0.54 to 0.85), left ventricular (LV) size (Gwet's AC₁, 0.73; 95% CI, 0.58 to 0.88), and LV contractility (Gwet's AC₁, 0.73; 95% CI, 0.58 to 0.88) utilizing EASy and FTTE.

There was an almost perfect agreement when assessing the presence of pericardial effusion (Gwet's AC₁, 0.98; 95% CI, 0.95 to 1.0) and RV contractility (Gwet's AC₁, 0.84; 95% CI, 0.74 to 0.95) and evaluating the motion of the interventricular septum (Gwet's AC₁, 0.92; 95% CI, 0.85 to 0.99). There was moderate agreement between the two reviewers when rating the image quality for the EASy

and FTTE examinations as 'good', 'adequate', and 'poor' (weighted Gwet's AC₁, 0.52; 95% CI, 0.38 to 0.67) (Table 2).

In two cases actionable findings were missed by EASy: 1) LV function assessed as normal in EASy was categorized as severely depressed by FTTE. This patient had morbid obesity (body mass index, 45 kg·m⁻²), and only basal segments of the LV were visualized well in the subcostal view. Based on FTTE LV function was classified as severely depressed consistent with Takotsubo cardiomyopathy with its key echocardiographic features of symmetrical circumferential regional dilation and dysfunction of the mid-ventricular and apical area, with preservation of the basal segments; 2) RV size assessed as normal on EASy, while being classified as severely dilated on FTTE. Upon further investigation such discrepancy was determined to be due to technique related to probe rotation.

Discussion

In the current study, we found substantial agreement between EASy and FTTE for qualitative assessment of ventricular size and LV systolic function as determined by two independent reviewers. Additionally, there was almost perfect agreement when assessing the presence of pericardial effusion, RV systolic function, and motion of the interventricular septum as surrogate for RV dysfunction. Regardless of the specific finding being evaluated, such level of agreement suggests that focusing on and obtaining images of the heart and IVC from a single window (subcostal) can provide sufficient qualitative diagnostic information in patients with hemodynamic instability compared with FTTE images acquired over three windows.

While the EASy examination can obtain similar information as the FTTE examination, it has several advantages over its more comprehensive counterpart. First, focusing on one window allows the novice echocardiographer such as anesthesiology residents to gain the basic competence in acquiring subcostal views while recognizing the sonographic anatomy, qualitative findings, and screening for overt pathology. Second, performing the EASy examination is faster than performing the FTTE examination as the clinician only needs to place the probe over one echocardiographic window.²⁰ Third, the subcostal window allows for imaging of the IVC, with small and collapsible IVC suggestive of hypovolemia and plethoric IVC suggestive of hypervolemia or obstructive physiology. When combined with upper lung views to look for fluid tolerance the entire examination can take only 3 to 4 min and provide important clinical information that could determine the

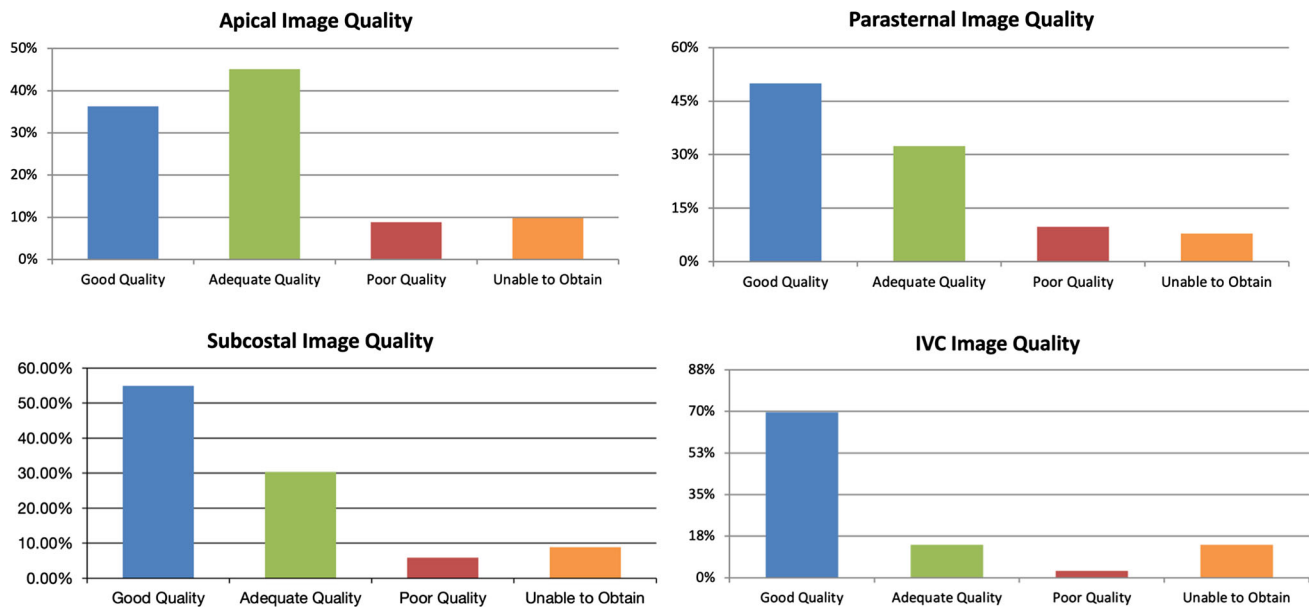


Fig. 2 FTTE examinations performed on 102 consecutive patients in postanesthesia care unit (PACU), surgical intensive care unit (SICU), and the operating rooms (OR); 96.9% revealed useful images that contributed positively to evaluation (at least one interpretable window).

Table 1 Baseline characteristics of patients and indications for examination

Age (yr), mean (SD)	65 (13)
Female sex, <i>n</i> (%)	48 (47%)
Body mass index (kg·m ⁻²), mean (SD)	28 (8)
Indication for exam	
Hypotension, <i>n</i> (%)	31 (30%)
Volume status, <i>n</i> (%)	18 (18%)
Respiratory distress, <i>n</i> (%)	8 (8%)
Cardiac arrest, <i>n</i> (%)	10 (10%)
Preoperative assessment <i>n</i> (%)	35 (34%)

Total *N* = 102. Sex was determined by patient-reported designation

SD = standard deviation

etiology of shock.²² A simple approach that focuses on one window can serve as the first step to achieve the basic competency in POCUS for both trainees and practicing clinicians. While mastering the EASy examination would not serve as the final destination of competence in POCUS, it can help clinicians gain familiarity and enhance visuospatial orientation and technical skills in urgent situations and overall confidence in employing this imaging modality during cardiac arrest.¹⁸

Our study has several limitations. Interpretable images were obtained in 80% of patients compared with FTTE (97%); nevertheless, many patients could be screened by novices rapidly leaving only 20% that require a more experienced person to perform FTTE. The novelty of comparing two echocardiography examinations precluded

the authors from performing a formal power analysis and determining the optimal number of examinations that should be completed to determine the level of agreement. The reporting system utilized during the current study is simplistic and does not allow for describing nuanced variation in such findings. Nevertheless, this basic reporting structure was utilized in an attempt to replicate the qualitative reports that novice echocardiographers may use in real-world settings. Additionally, while we are studying the agreement between two echocardiographic techniques, our results are certainly dependent upon whether FTTE had an impact on management of patient care. To minimize this phenomenon, the majority (66%) of the reviewed examinations involved clinical scenarios where echocardiography has traditionally been described

Table 2 Summary of agreement between cardiologist and anesthesiologist

	EASy by cardiologist & FTTE by anesthesiologist	FTTE by cardiologist & EASy by anesthesiologist	Overall
Pericardial effusion			
<i>N</i>	45	37	82
Gwet's AC1 (95% CI):	0.97 (0.91 to 1.0)	1.0 (1.0 to 1.0)	0.98 (0.95 to 1.0)
Agree	44 (98%)	37 (100%)	81 (99%)
Present	7 (16%)	7 (19%)	14 (17%)
Not present	37 (84%)	30 (81%)	67 (83%)
RV size			
<i>N</i>	45	37	82
Gwet's AC1 (95% CI):	0.81 (0.65 to 0.97)	0.54 (0.24 to 0.83)	0.70 (0.54 to 0.85)
Agree	39 (87%)	27 (73.0%)	66 (80%)
Normal	34 (87%)	21 (78%)	55 (83%)
Enlarged	5 (13%)	6 (22%)	11 (17%)
RV contractility			
<i>N</i>	45	37	82
Gwet's AC1 (95% CI):	0.83 (0.68 to 0.98)	0.86 (0.71 to 1.00)	0.84 (0.74 to 0.95)
Agree	39 (87%)	32 (86%)	71 (87%)
Good	36 (92%)	29 (91%)	65 (91%)
Depressed	3 (8%)	3 (9%)	6 (8%)
Interventricular septum			
<i>N</i>	45	37	82
Gwet's AC1 (95% CI):	0.93 (0.84 to 1.0)	0.91 (0.79 to 1.0)	0.92 (0.85 to 0.99)
Agree	42 (93%)	34 (92%)	76 (93%)
No bounce	42 (100%)	33 (97%)	75 (99%)
Bounce	0 (0%)	1 (3%)	1 (1%)
LV size			
<i>N</i>	45	37	82
Gwet's AC1 (95% CI):	0.74 (0.54 to 0.94)	0.72 (0.50 to 0.94)	0.73 (0.58 to 0.88)
Agree	38 (84%)	30 (81%)	68 (83%)
Normal	29 (76%)	26 (87%)	55 (81%)
Enlarged	9 (24%)	4 (13%)	13 (19%)
LV contractility			
<i>N</i>	45	37	82
Gwet's AC1 (95% CI):	0.61 (0.37 to 0.85)	0.86 (0.70 to 1.0)	0.73 (0.58 to 0.88)
Agree	35 (78%)	34 (92%)	69 (84%)
Good	26 (74%)	25 (73%)	51 (74%)
Depressed	9 (26%)	9 (26%)	18 (22%)
Image quality			
<i>N</i>	45	37	82
Weighted Gwet's AC1 (95% CI):	0.26 (N/A to 0.55)	0.56 (0.34 to 0.78)	0.52 (0.38 to 0.67)
Agree	28 (62%)	25 (68%)	53 (65%)
Good	17 (61%)	12 (48%)	29 (55%)
Adequate	11 (39%)	13 (52%)	24 (45%)
Poor	0 (0%)	0 (0%)	0 (0%)
Unable to decipher	0 (0%)	0 (0%)	0 (0%)

CI = confidence interval; EASy = echocardiographic assessment using subcostal only view; FTTE = focused transthoracic echocardiography; N/A = not calculable; RV = right ventricle; LV = left ventricle

as having direct clinical impact (i.e., hypotension, assessing volume status, and cardiopulmonary distress). As described, EASy can also miss certain pathologies due to limitations of the technique. To overcome these limitations, subcostal short axis view of the heart can be obtained when LV is not well visualized and special attention paid to visualize RV by tilting ultrasound probe to scan through the entire RV.

One limitation of the study is that image interpretation by novice sonographers was not examined. Since initial interpretation at the bedside was done together with the supervising anesthesiologist, this would provide biased estimates. Nevertheless, we were able to assess whether novice sonographers collected images sufficient to support clinical decision-making, as the ability of novice sonographers to collect high-quality images has implications for telemedicine, under conditions of massive influx of critically ill patients (e.g., patients with coronavirus disease), where residents can obtain EASy examinations as part of patient evaluation and then an expert interprets images during rounds or from home when on call. Further studies should compare novices' interpretation of EASy to experts' interpretation of FTTE.

In summary, when EASy examination can be obtained, it provides diagnostic information sufficient to aid in the assessment and management of patients with cardiopulmonary derangements in perioperative and critical care settings. Emphasizing and mastering one window can make echocardiography more accessible and appealing for any medical trainees or clinicians who are unfamiliar with this imaging modality. Further investigations are needed to measure the clinical impact that the EASy examination can have on patient outcomes.

Author contributions *Nibras Bughrara* participated in writing the protocol of the study, data collection, data analysis, and writing the manuscript. *J. Ross Renew* participated in writing the protocol, data analysis, and writing the manuscript. *Kenneth Alabre* participated in data collection and analysis and writing the manuscript. *Josh Schulman-Marcus* and *Krishnaveni Sirigaddi* participated in data collection and analysis. *Aliaksei Pustavoitau* participated in writing and editing the manuscript. *Elizabeth R. Lesser* participated in data analysis and writing the manuscript. *Jose L. Diaz-Gomez* participated in writing the protocol and editing the manuscript.

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