Goal-Directed Transthoracic Echocardiography During Advanced Cardiac Life Support

A Pilot Study Using Simulation to Assess Ability

Yonatan Y. Greenstein, MD;
Thomas J. Martin, MD;
Linda Rolnitzky, MS;
Kevin Felner, MD;
Brian Kaufman, MD

Introduction: Goal-directed echocardiography (GDE) is used to answer specific clinical questions that provide invaluable information to physicians managing a hemodynamically unstable patient. We studied perception and ability of house staff previously trained in GDE to accurately diagnose common causes of cardiac arrest during simulated advanced cardiac life support (ACLS); we compared their results with those of expert echocardiographers.

Methods: Eleven pulmonary and critical care medicine fellows, 7 emergency medicine residents, and 5 cardiologists board certified in echocardiography were enrolled. Baseline ability to acquire 4 transthoracic echocardiography views was assessed, and participants were exposed to 6 simulated cardiac arrests and were asked to perform a GDE during ACLS. House staff performance was compared with the performance of 5 expert echocardiographers.

Results: Average baseline and scenario views by house staff were of good or excellent quality 89% and 83% of the time, respectively. Expert average baseline and scenario views were always of good or excellent quality. House staff and experts made the correct diagnosis in 68% and 77% of cases, respectively. On average, participants required 1.5 pulse checks to make the correct diagnosis. Of house staff, 94% perceived this study as an accurate assessment of ability.

Conclusions: In an ACLS-compliant manner, house staff are capable of diagnosing management-altering pathologies the majority of the time, and they reach similar diagnostic conclusions in the same amount of time as expert echocardiographers in a simulated cardiac arrest scenario.
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Key Words: Echocardiography, Simulation, Sudden cardiac arrest, Advanced cardiac life support, Critical care, Fellow

It has been shown that a focused ultrasound examination performed in the emergency department on patients with nontraumatic hypotension can narrow the differential diagnosis in a timely manner.[1] Goal-directed echocardiography (GDE) is used to answer specific clinical questions that can provide invaluable and timely information to the critical care physician managing an unstable patient. For example, does the patient have cardiac tamponade, right ventricular dilatation or failure suggestive of a massive pulmonary embolism (PE), or marked left ventricular systolic dysfunction?

The Accreditation Council of Graduate Medical Education now requires that critical care ultrasonography, which includes GDE, be a mandatory component of critical care medicine fellowship training, surgical critical care fellowship training, and emergency medicine (EM) residencies.[2–4] Goal-directed echocardiography falls under the purview of basic critical care echocardiography as defined by The American College of Chest Physicians/Société de Réanimation de Langue Française (ACCP/SRLF) statement on competence in critical care ultrasonography.[5] It is well established that this can be performed successfully with a mixture of didactics, simulation, and hands-on training.[6–11] The use of GDE to guide management during cardiac arrests is a relatively new frontier with limited evidence-based research to guide clinicians. Multiple groups have proposed basic algorithms for integration of GDE into Advanced Cardiac Life Support (ACLS),[12–14] yet few studies assess feasibility and competency in GDE, leaving many questions unanswered.[15,16]

Because GDE is used by pulmonary and critical care medicine and EM physicians at our institution during cardiac arrests, we studied the ability of the house staff previously trained in GDE to accurately diagnose common causes of pulseless electrical activity (PEA) or asystole during simulated

From the Division of Pulmonary and Critical Care Medicine (Y.Y.G., T.J.M., K.F., B.K.), Department of Medicine, New York University Medical Center; New York Harbor VA Hospital (KF, BK, TJM); and Division of Biostatistics (L.R.), New York University School of Medicine, New York, NY.

Reprints: Yonatan Y. Greenstein, MD, 410 Lakeville Rd, Suite 107 New Hyde Park, NY 11040 (e-mail: lungdoc@yonatangreenstein.com).
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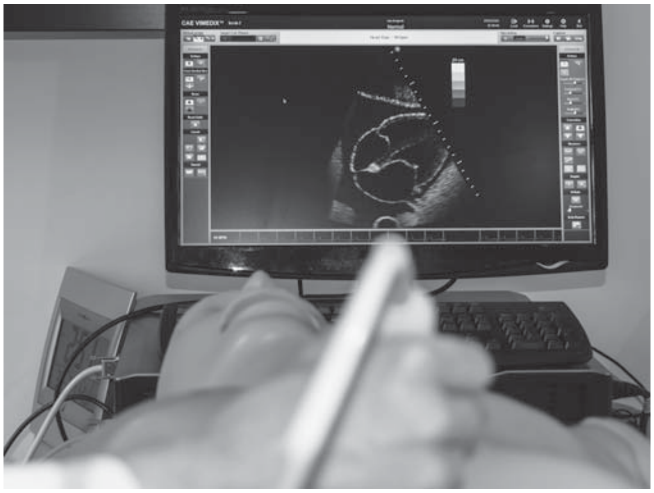

FIGURE 1. Photograph of the high-fidelity TTE simulator used in the study.

scenarios and compared them with those of expert echocardiographers. We also sought to determine if GDE can be performed in an ACLS-compliant manner, during pulse checks lasting no more than 10 seconds, which minimizes interruptions of proven interventions such as the delivery of high-quality chest compressions. Furthermore, we studied house staff perceptions of their ability to perform GDE before and after study commencement.

METHODS

Participants included house staff and experts for comparison. House staff were pulmonary and critical care medicine fellows (n = 11) and EM residents (n = 7) at New York University Medical Center during 2012 with previous training in GDE. Pulmonary and critical care medicine fellows were enrolled at any stage of their fellowship; however, all had received GDE training at the Cooperative Ultrasound Project course, a 3-day ultrasound course offered to first-year fellows in the greater New York area. Emergency medicine residents were in their third or fourth year of residency and had received GDE training during mandated ultrasound rotations. Five cardiologists board certified in echocardiography were enrolled to serve as experts. This study was approved by the institutional review board at New York University's School of Medicine (study # S12-00860), and all participants gave informed consent.

House staff answered a prestudy questionnaire (Appendix A). All participants were allotted 5 minutes to familiarize themselves with the high-fidelity transthoracic echocardiography (TTE) simulator (Vimedix, CAE Healthcare, Saint-Laurent, Quebec, Canada; Fig. 1) to minimize a potential learning curve effect. A baseline assessment was conducted in which participants were asked to obtain an image in each of 4 standard cardiac ultrasound windows: parasternal long axis, parasternal short axis, apical 4 chamber, and subcostal long axis (SCL). Participants were allowed 30 seconds per window (see Video, Supplemental Digital Content 1, http://links.lww.com/SIH/A209, which demonstrates the 4 baseline views obtained on the simulator).

After baseline data were obtained, participants were called into a total of 6 simulated PEA or asystolic arrest scenarios presented in a random order (Table 1). Upon entering the simulated cardiac arrest, participants were given a clinical vignette (Appendix B) from the patient's nurse, and they were instructed that their sole purpose during the ACLS resuscitation was to perform and interpret a GDE during pulse checks. Vignettes were designed to provide the pertinent information typically available to the clinician assessing an unstable patient and were not designed to mislead the participant. An actor stood on one side of the simulator and performed continuous chest compressions, pausing for 10 seconds during pulse checks. In the interest of time, chest compressions were performed for 30-second intervals rather than the standard 2-minute intervals recommended by the American Heart Association; participants were made aware of this deviation ahead of time. It was during the 10-second pulse checks that the participant was allowed to position the ultrasound probe and attempt to acquire and interpret an echocardiographic view of the heart (see Video, Supplemental Digital Content 2, http://links.lww.com/SIH/A210, which shows a participant attempting diagnosis during the cardiac tamponade and fine ventricular fibrillation [VF] scenarios). Participants were mandated during each scenario to start with the SCL view but were subsequently free to use any other standard view if subsequent pulse checks were necessary. All 6 scenarios in this study could be readily diagnosed with the SCL view. The other standard views were not necessary for diagnosis but could be useful for the clinician unsure of the SCL findings (see Video, Supplemental Digital Content 3, http://links.lww.com/SIH/A211, which demonstrates all 6 cardiac pathologies on the simulator). After each pulse check, the participants were asked if they had a diagnosis. Three ACLS-compliant GDE attempts were allowed, and if the participant did not offer a diagnosis, a final 20-second non–ACLS-compliant interval for GDE was allowed. Participants were debriefed on all scenarios (see Video, Supplemental Digital Content 4, http://links.lww.com/SIH/A212, which demonstrates part of a debriefing session) whereby an instructor walked them through the salient features of the case and ensured that they understood the GDE findings of

TABLE 1. Cardiac Arrest/PEA Pathologies and Accuracy

Scenario	Pathology	Overall Accuracy (n = 23)	House Staff Accuracy (n = 18)	Expert Accuracy (n = 5)
A	Fine VF	9%	11%	0%
B	Asystole	96%	94%	100%
C	Decreased left ventricular function	91%	89%	100%
D	Cardiac tamponade	100%	100%	100%
E	Hyperdynamic left ventricular function	52%	44%	80%
F	Right ventricular dilatation	74%	72%	80%

TABLE 2. Echocardiogram Scoring Paradigm

Score	Quality of View	Description of Echocardiogram Image
0	Poor	No image
1	Poor	<50% of total expected chambers and vessels visualized
2	Good	>50% of total expected chambers and vessels visualized
3	Excellent	100% of total expected chambers and vessels visualized

the scenario. Participants filled out a poststudy questionnaire (Appendix C). All echocardiography views were graded for quality on a modified but previously used scale of 0 to 3 (Table 2).[7] House staff performance was compared with the performance of the 5 expert echocardiographers.

For each participant, each baseline view was scored (Table 3), and the average quality of baseline views was determined for each of the 4 standard echocardiographic views. During the scenario phase, the best view achieved per scenario was scored, and the average quality of the 6 scenario views was calculated by the participant. The accuracy of diagnosis and time to diagnosis (TTD) was recorded. Time to diagnosis was reported in 10-second intervals, with each interval corresponding to a single pulse check.

All echocardiography scans performed by each participant were recorded and were later reviewed independently by 2 experts in GDE (T.J.M. and Y.Y.G.). Interrater reliability was calculated using the Cohen kappa statistic. Score discrepancies were reconciled by reviewing the scoring scale and reaching a consensus on the video at question.

Statistical Analysis and Sample Size Considerations

Primary outcome measure was diagnostic accuracy during the simulated cardiac arrest scenarios. Secondary outcome measures included perception of ability in GDE before and after study commencement, quality of GDE images obtained at baseline and during each scenario, TTD during each scenario, and diagnostic accuracy in an ACLS compliant time frame.

Our recruitment of participants was interrupted for several months in late 2012 and early 2013 due to suspension of operations and facility closure as a result of Superstorm Sandy. Sufficient statistical power for group comparison is lacking due to small samples sizes. Much of our results consist of descriptive summary data. Characteristics of the 3 groups and study results were summarized as means with standard deviations for continuous data and as percentages for categorical data. The relationship between the diagnostic accuracy and the quality of scenario views achieved was assessed with the nonparametric Spearman rank order correlation coefficient. We tested for a learning effect using general linear models to perform repeated measure analyses to determine if subjects performed better as they progressed through the randomized scenarios.

RESULTS

Inter-rater Reliability

The 2 independent reviewers agreed on the quality of view score 85% of the time (Cohen $\kappa = 0.079$). When disagreement existed, it was within one point on the quality scale.

TABLE 3. Quality of Baseline Views Obtained by Participants (n = 23)

Participant	Parasternal Long Axis	Parasternal Short Axis	Apical 4-Chamber View	Subcostal View	*Participant Average*
1	3	1	3	1	2
2	2	1	3	2	2
3	3	3	3	2	2.75
4	2	2	1	3	2
5	3	2	3	3	2.75
6	1	1	3	2	1.75
7	2	1	3	2	2
8	2	3	3	2	2.5
9	3	3	3	2	2.75
10	2	2	3	2	2.25
11	3	3	2	2	2.5
12	3	1	3	3	2.5
13	3	3	2	3	2.75
14	3	1	2	3	2.25
18	2	3	3	2	2.5
21	*3*	3	3	2	2.75
23	*2*	2	1	1	1.5
24	*2*	2	3	2	2.25
15	1	3	2	2	2
16	2	2	2	3	2.25
17	*3*	2	2	3	2.5
19	*2*	2	3	2	2.25
20	*1*	2	3	3	2.25
Baseline average	*2.44*	*2.06*	*2.61*	*2.17*	2.34

The last 5 participants, numbers 15, 16, 17, 19, and 20, are the expert group, and the rest are house staff.

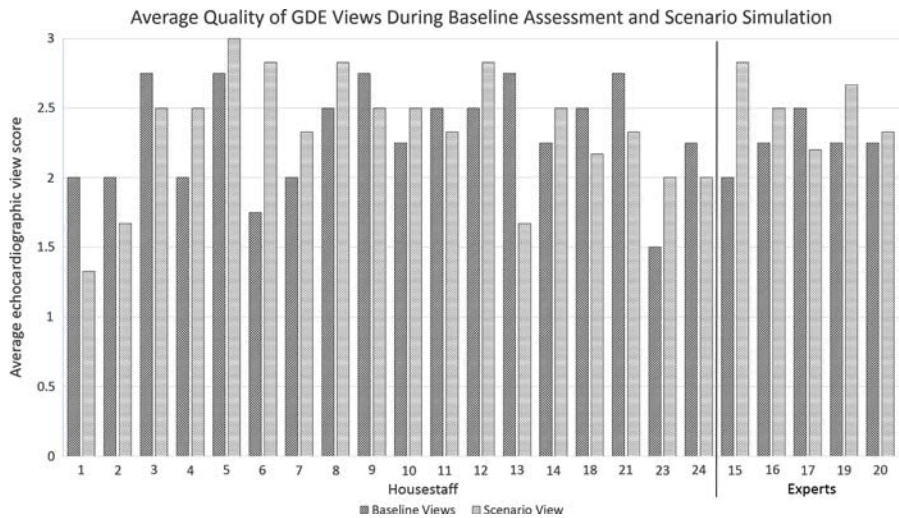

FIGURE 2. Average quality of GDE views during baseline assessment and scenario simulation by subject. House staff (n = 18); experts (n = 5).

Primary Outcome Measure

House staff and experts made the correct diagnosis in 68% and 77% of the simulated scenarios, respectively (Fig. 2), and the rates of correct diagnosis for each scenario are reported (Table 1). House staff made the incorrect diagnosis for 23% of the scenarios, and they did not offer a diagnosis for 8% of the scenarios. Experts made the incorrect diagnosis for 20% of the scenarios, and they did not offer a diagnosis for 3% of the scenarios.

Secondary Outcome Measures

House staff and experts made the correct diagnosis in an ACLS-compliant manner in 62% and 67% of the scenarios, respectively. The average baseline views obtained by house staff were of good or excellent quality 89% of the time, and all were able to acquire at least 2 different echocardiographic windows, which met criteria for good or excellent quality. The experts' average baseline views were always of good or excellent quality, and all experts were able to acquire at least 2 different echocardiographic windows, which met criteria for good or excellent quality.

The average scenario views by house staff were of good or excellent quality 83% of the time (Fig. 3). Of the house staff, 72% (13/18) acquired at least good quality views during each scenario. Of the house staff, 94% (17/18) achieved at least good views during 50% or greater of the scenarios. During each scenario, experts acquired at least 1 view, which met criteria for good quality or better.

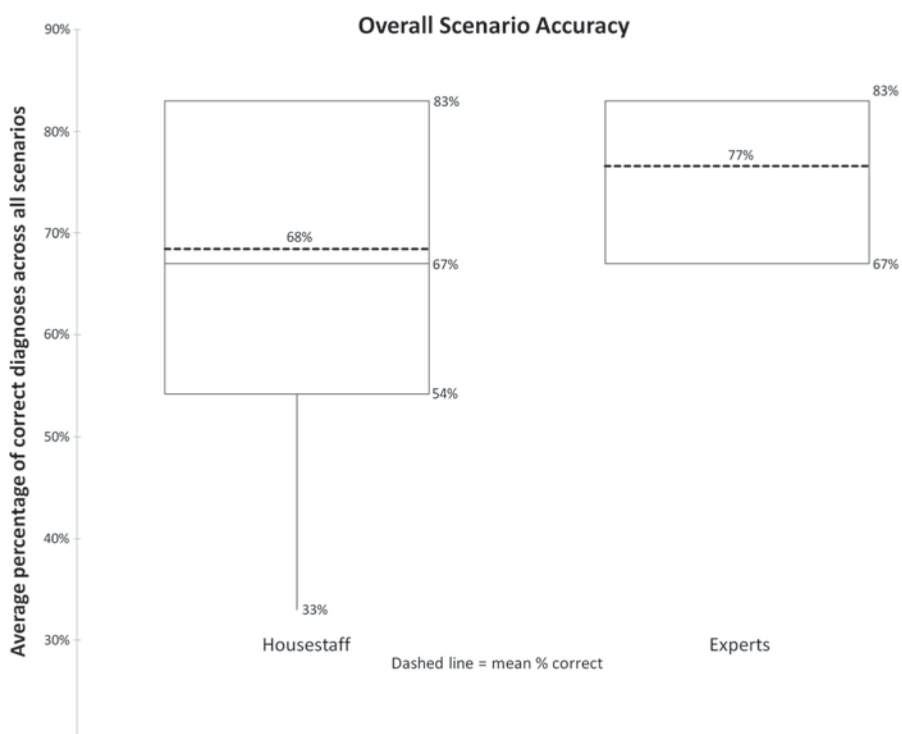

FIGURE 3. Box plot showing overall scenario accuracy. House staff (n = 18); experts (n = 5).

There was a weak relationship between quality of scenario views achieved and the likelihood for a participant to give the correct diagnosis ($\rho = 0.45$, $P = 0.03$). When a correct diagnosis was made, the TTD was 18 ± 8 seconds. When subjects made the incorrect diagnosis or offered no diagnosis, the TDD was 30 ± 8 and 38 ± 15 seconds, respectively. When an incorrect diagnosis was offered, 2 or more pulse checks were used, and when no diagnosis was offered, 3 or more pulse checks were used. Analysis of the data yielded no evidence of a learning effect; subjects were not more likely to improve TDD ($P = 0.11$), accuracy ($P = 0.20$), or quality of images ($P = 0.37$) as they progressed through the randomly ordered scenarios.

The number of all-time GDEs performed in real clinical scenarios before study commencement by house staff is reported (Table 4). There was no correlation between the number of GDEs performed before study enrollment and the quality of baseline or scenario views or the ability of the participant to make the correct diagnosis. The majority of the house staff perceived this study as an accurate assessment of their ability and enjoyed participating in the study (Table 4).

DISCUSSION

At many institutions GDE is increasingly being used to guide management during cardiac arrest situations. This noninvasive window to the heart has the potential to quickly uncover reversible causes of cardiac arrest not apparent during the physical examination and provide useful information to treating physicians. To our knowledge, this pilot study is the first that sought to determine if GDE can be successfully performed during cardiac arrests in an ACLS-compliant manner. A study by Breitkreutz et al[15] sought to answer this question by performing a GDE while ACLS was being conducted on pulseless patients in the emergency department. Although a high success rate was reported, images obtained were not stored, and thus, it is impossible to know the quality of the views obtained and if they were interpreted correctly. In addition, the prevalence of relatively rare causes of cardiac arrest such as cardiac tamponade and right heart strain from a massive PE was low, making it impossible to draw conclusions about the capability of the physicians studied to make these crucial diagnoses.

TABLE 4. House staff Pre- and Post-study Questionnaire Data (n = 18)

Before Study Commencement	
No. GDEs performed	
1–5	17%
6–15	17%
16–30	50%
>30	17%
Poststudy Perceptions	
Study perceived as accurate assessment of ability	
Strongly disagree/disagree	0%
Neutral	6%
Agree	50%
Strongly agree	44%
Increased comfort with GDE after study	
Strongly disagree	0%
Disagree	6%
Neutral	11%
Agree	61%
Strongly agree	22%
House staff enjoyment in participation	
Agree	33%
Strongly agree	67%

Our study demonstrated that trained house staff and expert participants were able to perform and interpret a GDE during simulated cardiac arrest scenarios in an ACLS-compliant manner the majority of the time. Furthermore, trainees and experts achieved similar diagnostic accuracy in the same time frame. It may seem surprising that we did not identify a relationship between quality of baseline or scenario GDE views and diagnostic accuracy during the simulated scenarios. We believe this is the case because the majority of views obtained were at least of good quality, which provides enough information for the participant to make a diagnosis. The skills demonstrated during the simulated scenarios are directly translatable to real-world ACLS. With the growing ubiquity of portable ultrasonography in the hospital environment, this study provides evidence for the feasibility of performing GDE during cardiac arrest situations.

Using a computerized TTE simulator is advantageous in that it allows evaluators to test participant ability to both acquire and interpret images, which are typically only present during high-risk, low-frequency events. Beraud et al[17] recently demonstrated the utility of using a TTE simulator to assess participant skill after a novel GDE training curriculum. Although participants were not placed under the same time constraints as those in our study, they reported comparable TTD.

At study conclusion, participants felt more comfortable in their abilities. They appreciated the debriefing period, whereby they were able to spend more time acquiring images and interpreting the pathologies that they encountered. Such opportunity is seldom feasible with real patients and is another advantage of incorporating simulation into training and assessment. The ability to spend as much time as is needed getting hands-on training to understand the echocardiographic features of different pathologies is invaluable.

Ventricular fibrillation, which is often amenable to defibrillation, can be confused with asystole on cardiac monitors and/or electrocardiogram. The distinction between the 2 has a profound impact on patient management and prognosis given dismal outcomes in asystole compared with VF.[18] Several studies report diagnosing VF using echocardiography.[18–20] It is intuitive that distinguishing VF from asystole with echocardiography is more challenging than identifying more obvious causes of cardiopulmonary arrest such as cardiac tamponade; however, the sensitivity and specificity of TTE for diagnosing VF are unknown. In our study, only 9% of the participants correctly identified fine VF. It is important to recognize that the low rate of correct diagnosis of VF in our study may be caused by the performance of our participants and a lack of awareness of this diagnosis; however, it may also be a limitation of our simulator's ability to accurately portray VF on an echocardiogram. Although not formally assessed, our expert echocardiographers thought the VF simulation had good fidelity. Given the management-altering implications of correctly identifying this rhythm, we believe that GDE training should include this diagnosis and efforts should be increased to improve its identification. Goal-directed echocardiography training should also focus on the echocardiographic findings of severe hypovolemia and right ventricular pressure overload.

Currently, no standard exists to guide physicians performing GDE in reporting their findings. As GDE is performed in the hope of having immediate treatment implications, findings should be reported immediately to the treating physicians. A GDE may show a clear cause of the cardiac arrest. Alternatively, a GDE may not elucidate the cause. In such a case, it is useful for the physician to report their findings to the treating physicians. For example, a physician may report as follows: "GDE performed. No pericardial effusion present. Right and left ventricular size appears normal. There is no end-systolic effacement of the left ventricular cavity. There is cardiac contractile activity. I do not suspect cardiac tamponade, right heart failure from a massive PE, or hypovolemic shock to be the cause of this patient's cardiac arrest. I do not see evidence of asystole or ventricular fibrillation." Finally, the GDE images may be of poor quality, and thus, an accurate assessment cannot be made. It is important that the physician performing the study relay this information to the treating team.

One might interpret our data more cautiously, noting that a diagnosis was made in 93% of the scenarios and in 22% of those, the diagnosis was wrong. There is clearly room for improvement; however, we urge readers to consider the following: it is possible that participants were unsure of the diagnosis in some of those cases but, because of our study design, felt compelled to offer one. Although this could occur in a real patient scenario, such a hypothesis needs to be confirmed in future studies. Misdiagnoses compared with correct diagnoses took longer on average to make. Physicians should keep this in mind when performing GDE, and this should be studied in the future. In addition, GDE is useful in cardiac arrest situations where the cause of the arrest is unknown. At that point, physicians are only able to treat algorithmically and to offer empiric therapies. Mortality remains unacceptably high in such cases. House staff and expert correct diagnosis rates of 68% and 77%, although imperfect, do have potential to save many lives. Furthermore, analysis of accuracy with the elimination of the fine VF scenario, which was diagnosed correctly in only 9% of cases, shows that house staff and experts correctly diagnosed the cause of the cardiac arrest in 80% and 92% of cases, respectively. Nonetheless, future GDE training should focus on the time-constrained setting of an ACLS resuscitation and should emphasize that it is okay to notify the treating team that GDE was unable to yield a diagnosis. Another measure that would likely improve accuracy would be for the GDE to be recorded and quickly reviewed at the bedside. In this way, the physician acquiring the images can take a few extra moments to process the data, and other treating clinicians with knowledge of GDE can be involved in the interpretation. In this study, participants did not have such an opportunity.

Limitations

Our study has several limitations. The sample size was limited as a result of operational interruptions because of the Superstorm Sandy. Nonetheless, we believe that our data provide a strong foundation to inform future research in this area. Simulation has inherent advantages and disadvantages which have been well described in the literature. We attempted to create a realistically stressful environment to simulate an in-hospital cardiac arrest and believe that we observed good buy-in from our participants.

Computerized echocardiography simulators are a new technology, and the device we used closely simulated real world echocardiography. We included ribs shadows in the simulation so as to create realistic difficulties in finding an adequate cardiac window. In this study, participants were naive to the simulator, thus decreasing the chance that a participant could have a familiarity advantage with the simulator. Goal-directed echocardiography on hospitalized patients is notoriously challenging as optimal patient positioning and lighting are rarely encountered and electrodes and wires are often in the way of the ultrasound beam. With that in mind, the level of difficulty of image acquisition on this simulator closely mimics that of our patients; however, the reader may wish to consider our results to represent the upper bounds on expected real-world performance. To date, no studies exist, which validate the use of a particular echocardiography simulator.

We chose to use cardiologists board certified in echocardiography as our expert group. Although they do serve as a good comparison group, it is important to note that they actually perform relatively few echocardiograms and rather spend the majority of their time interpreting echocardiograms obtained by a trained technician. Future studies should consider using expert-level EM physicians and intensivists in addition to cardiologists.

Because our study did not account for duration of elapsed time between GDE training and enrollment, we cannot comment on the presence or absence of skill decay. This should be accounted for in future studies.

CONCLUSIONS

As GDE becomes integrated into ACLS, institutions will need to ensure that physicians performing GDE are sufficiently skilled to do so. The use of computerized echocardiography simulators provides a practical way to expose clinicians to both common and rare management-altering pathology in an environment, which closely simulates the intensity and time constraints of an ACLS resuscitation.

The use of a high-fidelity TTE simulator is a novel and practical method of assessing skill and training house staff in GDE. This study provides data to suggest that house staff with previous GDE training reach similar diagnostic conclusions in the same amount of time as expert echocardiographers in a simulated cardiac arrest scenario. Using GDE in an ACLS-compliant manner, house staff are capable of diagnosing management-altering pathologies the majority of the time. A larger study is needed to confirm the observations of this pilot study.

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APPENDIX:

Appendix A. Prestudy Questionnaire

Cardiac Arrest Prestudy Questionnaire

Instructions

The purposes of this brief questionnaire are to assess your current thoughts and attitudes of GDE and to get an idea of how you currently implement GDE in your everyday clinical practice. Goal-directed echocardiography is the use of echocardiography to answer specific clinical questions designed to help guide immediate patient care decisions.

1. I received formal training in GDE before the start of my residency/fellowship.
   a. True
   b. False

If you answered True, what was the approximate date of your training?

2. I received formal training in GDE as part of my residency/fellowship.
   a. True
   b. False

3. The majority of GDE that I have learned has come from (answer only if you previously answered True to questions 1 or 2):
   a. A formal curriculum given during the course of 1 to 4 days
   b. Hands-on learning on the fly with an attending physician during direct patient care
   c. Video tapes and Web-based resources
   d. Textbook and journal articles

4. I have performed approximately ____ goal-direct ECHOs.
   a. 0
   b. 1–5
   c. 6–15
   d. 16–30
   e. >30

5. I am comfortable obtaining the following cardiac windows when performing an echocardiogram (circle all that apply).
   a. Parasternal short axis
   b. Parasternal long axis
   c. Apical 4 chamber
   d. Subcostal

6. When a patient has a cardiac arrest and I am at the bedside managing him or her, I feel comfortable enough with my GDE skills to perform a GDE and use the information obtained to guide clinical management.
   a. Strongly disagree
   b. Disagree
   c. Agree
   d. Agree, but I prefer to have an experienced attending physician with me to verify my findings
   e. Yes, but strongly agree

7. Goal-directed echocardiography competency by noncardiologist physicians has been studied in the past. I believe that a noncardiologist physician GDE is ______ as accurate in image acquisition and interpretation as an expert cardiologist.
   a. <20%
   b. 20%–50%
   c. 51%–80%
   d. >80%

8. What is your specialty?
   a. Pulmonary and critical care medicine
   b. EM
   c. Anesthesia
   d. Other ________________________

9. What is your level of training (eg, PGY1)?
   ____

Appendix B. Clinical Vignettes

Clinical Vignettes

Scenario A. *Cardiac Arrest with Fine VF*

HPI

A 59-year-old man with a medical history of uncontrolled non–insulin-dependent diabetes mellitus and hyperlipidemia, who experienced a large anterior wall myocardial infarction 14 hours ago and received a bare metal stent to his left anterior descending coronary artery.

Current Medications

- ASA 325 mg PO daily
- Clopidogrel 75 mg PO daily
- Metoprolol 25 mg PO BID
- Lisinopril 5 mg PO daily
- Rosuvastatin 20 mg PO qhs
- Insulin glargine 25units SC qhs
- Insulin aspart 8 units SC AC TID

Recent Laboratory Values

- CBC: 5.9 > 13.1/39.3 < 278
- BMP: 139, 4.3, 105, 26, 7/0.8, Glu 275, Ca 9.7
- LFT: Alb 4.6, TBili 0.4, AST/ALT 14/19, Alk phos 74
- Troponin 27

Scenario B. *Cardiac Arrest With Asystole*

HPI

A 73-year-old woman with a medical history of metastatic breast cancer, who was initially admitted with neutropenic fever and found to have severe sepsis secondary to multifocal pneumonia. She was given broad-spectrum antibiotics, intubated, and transferred to the intensive care unit.

Ventilator Settings

VC, Vt 550, PEEP 5, 100% FIO_2

Current Medications

- Norepinephrine 32 μg/min
- Phenylephrine 200 μg/min
- Vancomycin 1 g IV q12
- Cefepime 2 g IV q8
- ASA 81 mg PO daily
- Simvastatin 20 mg PO qhs

Recent Laboratory Values

- CBC: 0.2 > 11.2/33.6 < 184, (96% neutrophils)
- BMP: 133, 3.7, 99, 30, 18/1.2, Glu 112, Ca 10.1
- LFT: Alb 4.1, TBili 0.2, AST/ALT 21/28, Alk phos 87
- Blood cultures: gram-positive cocci in cluster (4/4 bottles)

Scenario C. *Dilated Cardiomyopathy With Severe Left Ventricular Systolic Dysfunction*

HPI

A 58-year-old man smoker with a medical history of poorly controlled hypertension, who was admitted to the intensive care unit after initially presenting to the emergency department with complaints of dyspnea on exertion, 3 pillow orthopnea, and bilateral lower extremity swelling. Chest x-ray showed pulmonary vascular congestion with cephalization. He was given furosemide 40 mg IV and was admitted to the general medicine floor.

Current Medications

- Furosemide 40 mg IV q12
- Metoprolol 25 mg PO q12
- ASA 81 mg PO daily
- Simvastatin 40 mg PO qhs

Recent Laboratory Values

- CBC: 8.9 > 14.1/42.3 < 310
- BMP: 141, 4.3, 105, 22, 10/0.9, Glu 97, Ca 9.6
- LFT: Alb 4.5, TBili 0.1, AST/ALT 5/7, Alk phos 120

Scenario D. *Large Pericardial Effusion With Tamponade Physiology*

HPI

A 65-year-old man with a medical history significant for hypertension, hyperlipidemia, and nonobstructive coronary artery disease, who was admitted to the intensive care unit after presenting to the emergency department with complaints of dyspnea and dizziness with coughing.

Current Medications

- Lisinopril 10 mg PO daily
- ASA 81 mg PO daily
- Rosuvastatin 40 mg PO qhs

Recent Laboratory Values

- CBC: 6.4 > 13.5/40.5 < 213
- BMP: 139, 3.6, 107, 23, 14/1.0, Glu 120, Ca 10.0
- LFT: Alb 3.9, TBili 0.5, AST/ALT 24/19, Alk phos 85

Scenario E. *Severe Hypovolemia With a Hyperdynamic Left Ventricle*

HPI

A 78-year-old woman with a medical history significant for hypertension and Alzheimer dementia, who was admitted to the intensive care unit after being brought in by emergency medical services because she was found down in her home. Her only complaint upon arrival was dysuria, but she was noted to be febrile, tachycardic, and hypotensive. Her working diagnosis at the time of admission was severe sepsis secondary to a urinary tract infection.

Current Medications

- Normal saline 150 mL/h
- Ceftriaxone 1 g IV q24
- ASA 81 mg PO daily

- Memantine 10 mg PO BID
- Donepezil 5 mg PO qhs

Recent Laboratory Values

- CBC: 14.2 > 12.7/38.1 < 356 (89% neutrophils)
- BMP: 149, 4.1, 115, 24, 40/1.9, Glu 120, Ca 10.0
- LFT: Alb 3.2, TBili 0.3, AST/ALT 18/17, Alk phos 98

Scenario F. *Right Ventricular Dilation From a Massive PE*

HPI

A 46-year-old man with no significant medical history, who was admitted to the medicine wards with complaints of pleuritic chest pain for 1 day. His admission chest roentgenogram was unremarkable, and serial troponin I measurements were negative.

Current Medications

- Ibuprofen 600 mg PO q4 PRN pain
- ASA 81 mg PO daily

Recent Laboratory Values

- CBC: 9.1 > 14.2/42.6 < 305
- BMP: 137, 3.9, 109, 23, 7/0.9, Glu 108, Ca 9.7
- LFT: Alb 4.2, TBili 0.4, AST/ALT 11/12, Alk phos 107

Appendix C. Poststudy Questionnaire

Cardiac Arrest Poststudy Questionnaire

Instructions

The purpose of this brief questionnaire is to assess your thoughts and attitudes toward the study in which you just participated. Your feedback is valuable, and your participation is greatly appreciated.

10. I believe this exercise accurately evaluated my GDE skill set.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

11. I enjoyed participating in this study.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

12. I feel more comfortable and confident in my personal ability to perform GDE and obtain a diagnosis in the setting of cardiac arrest.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

13. I believe using an echocardiogram simulator is a practical means of assessing competence with GDE.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

14. Please provide any other feedback as regards your participation in this study (write below):