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Brief Report

Feasibility and accuracy of speckle tracking echocardiography in emergency department patients☆,☆☆,★

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ABSTRACT

Background: Speckle tracking echocardiography (STE) is a novel technology that measures regional wall-motion abnormalities that may speed diagnosis and intervention of acute coronary occlusion in Emergency Department (ED) patients with non-ST elevation ACS (NSTE-ACS). STE provides an objective measurement of myocardial strain that is superior to visual assessment of wall motion when performed as part of a point-of-care (POC) echocardiogram. We determined the feasibility and preliminary accuracy of POC STE operated by emergency providers when compared to comprehensive echocardiography or final diagnosis of ACS.
Methods: We retrospectively reviewed 187 emergency provider POC echocardiograms with STE from 7/2014–5/2016 for suspected ACS at a large academic trauma center. Feasibility of POC STE was determined by calculating the percentage of complete exams (adequate apical 4-chamber and parasternal short axis views) out of all STE exams. We then used two different criterion standards for calculating diagnostic accuracy of STE: comprehensive echocardiograms with wall motion abnormalities or formal diagnosis of ACS based on elevated cardiac troponins, unstable angina, percutaneous coronary intervention, or coronary artery stenosis >70% on catheterization.
Results: Of 187 STE studies performed, 75 (40%) were considered complete. Ultrasound-experienced providers had higher rates of complete exams (65% vs. 35%, $P = 0.01$). 16 of 75 exams (21%) were positive for myocardial strain, and of these 16 (100%) were admitted, 12 (75%) had positive troponins, 6 (46%) had positive comprehensive echocardiograms, and 3 (19%) had PCI or >70% stenotic lesion on catheterization. Compared with comprehensive echocardiography, POC STE had 35% sensitivity, 70% specificity, 46% positive predictive value (PPV), and 59% negative predictive value (NPV). Compared with formal diagnosis of ACS, POC STE had 29% sensitivity, 88% specificity, 75% positive predictive value (PPV), and 51% negative predictive value (NPV).
Conclusion: STE is a potentially feasible adjunct to standard bedside echocardiography in ED patients with suspected ACS when operated by experienced ultrasound-trained physicians in the ED. This data shows STE performed by emergency providers is not yet sensitive enough alone to diagnose ACS, and has low accuracy when compared to comprehensive echocardiography. However, the PPV and specificity improve when performed by expert ultrasound-trained providers. STE should be considered for inclusion in the Emergency Ultrasound Fellowship curriculum.

1. Introduction

Over 6 million Americans present to the Emergency Department (ED) annually with suspected acute coronary syndrome (ACS) [1] and electrocardiography (ECG) has a limited sensitivity of only 70% to detect acute coronary occlusion. Over 40% of patients diagnosed with acute coronary occlusion have ECG without evidence of ST elevation, and therefore may not meet criteria for early reperfusion therapy [2]. Patients with non-diagnostic ECGs often have delayed diagnosis and intervention, which leads to higher morbidity and mortality. Point-of-care (POC) echocardiography has been well-established as a rapid and non-invasive tool for Emergency Providers (EP) to identify acute myocardial injury. The addition of speckle tracking software to POC

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echocardiography is a novel technology that detects the magnitude, or percent "strain," of myocardial deformation. Few EPs in the United States currently perform bedside speckle tracking echocardiography (STE) as part of a diagnostic ultrasound, and only two groups have published reports on the potential applications and benefits to the ED [3,4].

Our ED has used speckle tracking technology since July 2014, and the ED sonographers, ultrasound fellows, and many ED faculty are well-versed in its use. Routine POC echocardiography relies on an interpreting physician to visually estimate a possible wall motion abnormality, and is heavily operator dependent [5]. Left Ventricular Ejection Fraction and regional wall motion can be normal in 25–76% of cases, so transthoracic echocardiography is not informative in almost half of the patients presenting with NSTE-ACS [6]. Prior studies have shown that speckle tracking technology is superior to the visual assessment of wall motion when performed as part of an echocardiogram [2,6].

Acute coronary occlusion causes changes in left ventricular systolic function, and subtle endocardial strain may occur within seconds. In patients without diagnostic evidence of STE elevation on ECG, POC echocardiography has the potential to identify early wall motion abnormalities even before the return of myocardial biomarkers. ED POC echocardiography is a well-established, rapid, and non-invasive two-dimensional imaging modality routinely used to identify global systolic function in the acute setting. POC echocardiography in the ED may be performed within the timeframe where reperfusion therapy still may lead to significant myocardial recovery [2]. Segmental wall motion abnormalities may be subtle, however, and can be difficult to interpret even for a well-trained POC sonographer. Based on current literature, the addition of speckle tracking to routine POC echocardiography may help differentiate which patients with suspected ACS would benefit from urgent revascularization [2,3,4,5]. Published literature suggests that STE has the potential to lead to earlier diagnoses of not only acute myocardial infarction, but also heart failure, pulmonary embolus, and sepsis [4]. Advanced STE software is available on many point-of-care machines, but not yet widely used in an ED setting to detect these early changes.

We performed a data analysis from 7/1/14 to 5/3/16 to better understand the role of speckle tracking technology in the ED and the feasibility of use by EPs. We determined the preliminary accuracy of POC STE operated by EPs when compared to current criterion standards of comprehensive echocardiography or final diagnosis of ACS.

2. Methods

2.1. Study design and patients

We performed a retrospective chart review. We obtained data from patient medical records reviewed in EPIC (Verona, WI), and ED point-of-care ultrasound workflow management software in QPath by Telexy Healthcare (Seattle, WA). Subjects included all adult patients (≥age 18) who presented to the ED with suspected ACS between July 1, 2014 and May 3, 2016 and underwent POC STE as part of their ED evaluation. Subjects were included if the following criteria were met: (1) Presenting complaint led clinicians to suspect ACS, (2) Patient name, date, MRN, and exam type were correctly labeled, (3) Ultrasound study was transferred into PACS system, (4) Interpretation of POC echocardiogram by ED faculty was present in EPIC, (5) Point-of-care echocardiogram included 4 standard views (parasternal long axis, parasternal short axis, apical 4-chamber and subxiphoid), and at least 2 adequate speckle tracking windows including apical 4-chamber and parasternal short axis. This study was reviewed and approved by the Institutional Review Board with waiver of informed consent.

2.2. Setting

Academic Level 1 Trauma Center with >100,000 annual visits serving a diverse population of patients from both urban and surrounding suburban regions.

2.3. Image acquisition

Point-of-care echocardiograms were performed using a Toshiba Aplio 300 ultrasound with wall motion tracking technology (Canon Medical Systems, Tustin, CA) using a phased array transducer. Completed exams were wirelessly transmitted to and stored in QPath.

Speckle-based strain echocardiography uses software available on POC ultrasound machines which detects the magnitude of myocardial deformation. "Strain" is a term that describes the percentage change in length of a myocardial segment during a given period. It has a unit of percent, and measures the percent change in length in a single segment of heart [7,9]. As a result of the scatter of the ultrasound beam by the tissues, a standard gray-scale ultrasound image is composed of small clusters of pixels, or speckles [7]. The STE software is capable of identifying these speckles and tracking them frame-by-frame to determine if they are moving in relation to each other, in what direction, or not at all.

Measurements of "normal global strain" are characterized by a consensus statement from the American Society of Echocardiography (ASE) and European Association of Echocardiography (EAE). Based on 2-Dimensional STE, the lower limits of −18.5% may be normal for global strain [11]; however, image quality, orientation, inter-vendor differences, and physiological factors have not yet been studied and a normal value may vary [10]. Based on the patient's ECG tracing, the ultrasound system identifies mid-systole and the provider manually traces the endocardial border. The computer then assigns speckle regions and calculates systolic strain for 16–18 segments of LV, depending on the manufacturer's software. This result is displayed on a linear graph as percent change over time (x-axis is time and y-axis is percent strain with green hashed vertical line representing aortic valve closure) [4], and quantifies myocardial deformation. Strain analysis, therefore, captures the three-dimensional nature of cardiac motion.

When our STE studies were performed, providers in our ED were using pattern recognition to interpret a study as normal versus abnormal. For example, our software displayed systolic strain on a linear graph depicting 6 colored lines that correspond to a segment of the myocardium, and the software displayed a color-coded label on each LV wall segment on the STE image. A normal STE graph was defined as one in which the lines form a uniform overlapping pattern with a negative percent change in length over time. When the graph lines overlapped in all segments, this suggested to the interpreting physician that the wall motion was consistent in all segments (Fig. 1). When one or more of these lines did not overlap, the change in strain over time in one or more segments differed from the others, which may have indicated a wall motion abnormality. For the purposes of this study, an abnormal STE exam was defined as one in which the pattern of the graph was not uniform (Fig. 2).

STE was performed and interpreted by Emergency Department residents, ultrasound fellows, ultrasound fellowship-trained faculty, faculty members without ultrasound fellowship training, and ED ultrasound technicians. Our ED employs Registered Diagnostic Medical Sonographer (RDMS) certified technicians in the ED who provide education and scanning assistance at the bedside. Every study performed by a resident, fellow, or ED ultrasound technician had been reviewed and interpreted in real-time by the ED faculty member who was the department attending at the time of service. The interpretation was documented in the EMR. For purposes of this report, ultrasound trained faculty, ultrasound fellows, and ED ultrasound technicians were considered "experienced" operators. Faculty without ultrasound fellowship training and residents were considered "inexperienced" operators.

2.4. Measurements and outcomes

We gathered patient information obtained in the ED as well as all information obtained during hospitalization admission on a standardized data collection form. Pertinent information included presenting

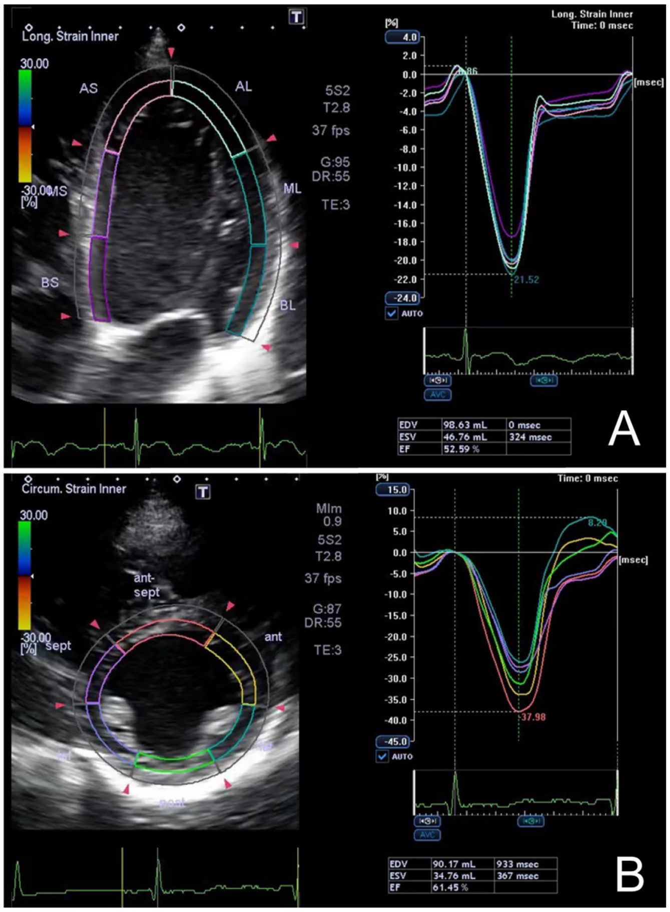

Fig. 1. Speckle Tracking Echocardiography with normal strain patterns. A: Apical four-chamber view with myocardium traced and labeled by STE software. Corresponding longitudinal strain curves to right illustrate a normal strain pattern. B: Parasternal short axis view with circumferential strain curves to right illustrating a normal strain pattern.

complaint, cardiac laboratory results, bedside echocardiogram interpretation, medical decision making during ED visit, admission or discharge diagnosis, cardiac treatments given, comprehensive echocardiogram interpretation, cardiac catheterization results, disposition, and follow up readmissions, or deaths at 30 days. Data collected from QPath included the numbers and types of views obtained during speckle tracking echocardiogram, the ultrasound operator, the indication for bedside echocardiogram, and the attending physician of record.

We used two different criterion standards for calculating diagnostic accuracy of STE: comprehensive echocardiograms with wall motion abnormalities or formal diagnosis of ACS based on elevated cardiac troponins consistent with NSTEMI, presence of unstable angina, percutaneous coronary intervention, or coronary artery stenosis >70% on catheterization.

2.5. Troponin assay

At the time of the study, testing of cardiac troponin in ED patients was performed by laboratory technicians in a stat lab using the cTn-T. With this assay, the 99th percentile upper reference limit of the normal reference population is 0.01 ng/mL with a coefficient of variation of 10% at that level. A positive ED troponin was therefore considered a cTn-T > 0.01 ng/mL.

2.6. Statistical analysis

Continuous data are expressed as a mean ± SD or as median (interquartile range). Comparisons between group means were analyzed using Student's *t*-test and Fisher's exact test as appropriate. Categorical data are presented as a number (%) and were analyzed by Chi Square or exact test. A *P*-value of 0.05 was considered statistically significant.

3. Results

3.1. General characteristics

We reviewed 187 point-of-care echocardiograms with STE in QPath. Studies were considered complete if they included at least 2 adequate STE windows including an apical 4-chamber and parasternal short axis view. We excluded 104 studies for having only 1 speckle tracking window obtained, and 7 more excluded for missing either an apical 4-chamber or parasternal short axis view. The excluded studies were characterized as incomplete for purposes of this report.

Of 187 STE studies reviewed, 75 (40%) were considered complete and 112 (60%) were considered incomplete. Experienced providers performed a higher number of 49 complete exams while inexperienced providers performed 26 of the complete exams (65% vs. 35%, $P = 0.01$).

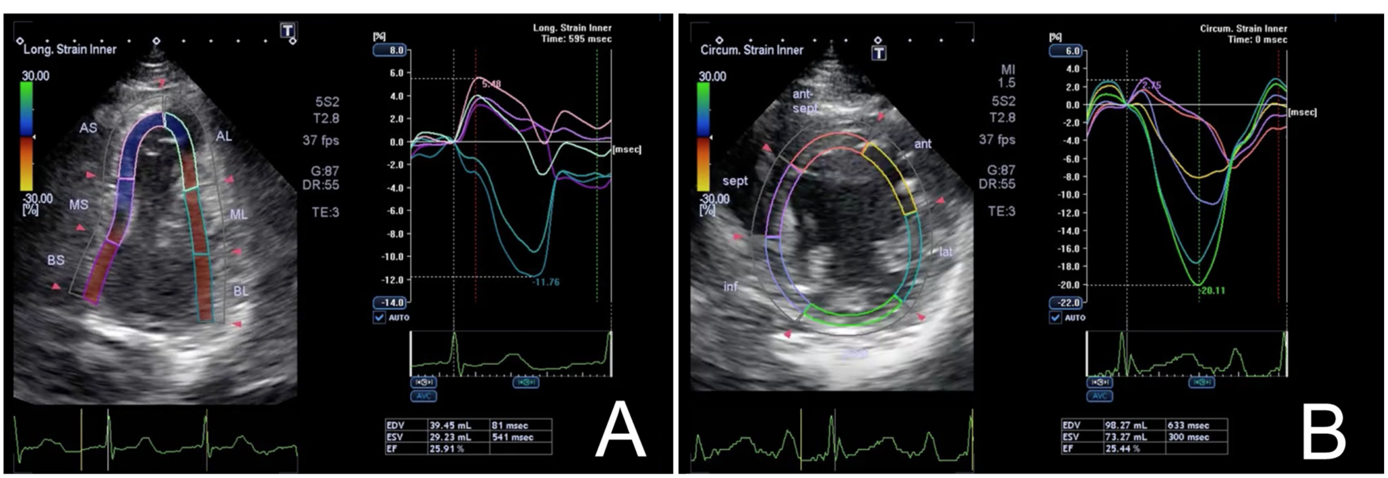

Fig. 2. Speckle Tracking Echocardiography with abnormal strain patterns. This 44 year old female patient presented to the ED with chest pain. Initial EKG was non-ischemic and cTn-T was mildly elevated at 0.03 mg/mL. STE was performed at the bedside by EPs. Based on the abnormal strain pattern, the catheterization laboratory was activated and patient was found to have acute coronary occlusion. Three drug-eluting stents were placed in the LAD and RCA. A: Apical 4-chamber view showing decreased longitudinal strain pattern in the apical lateral, apical septal, mid septal, and basal septal segments. B: Parasternal short axis view showing decreased circumferential strain in the anterior, anterior-septal, septal and inferior walls.

Table 1
General characteristics.

Baseline characteristics	Value
Gender	
Male	54 (72%)
Female	21 (28%)
Age	
18–40	9 (12%)
41–60	45 (60%)
61–80	20 (27%)
>80	1 (1%)
Echo indication	
Chest pain	42 (56%)
Other abnormal clinical finding	20 (27%)
Shortness of breath	10 (13%)
Abnormal EKG	5 (7%)
Tachycardia/palpitations	3 (4%)
Shock	2 (3%)
Altered mental status	1 (1%)
Congestive heart failure	1 (1%)
Syncope	1 (1%)
Qpath operator	
Not recorded	35 (47%)
Fellow	16 (21%)
ED ultrasound technician	12 (16%)
Resident	10 (13%)
Attending	2 (3%)

Data are presented as mean or n (%).

Inexperienced providers performed 36 (32%) and experienced providers performed 28 (25%) of the incomplete exams. The remaining 48 (43%) incomplete exams did not have an operator specified or recorded.

Of the 75 complete exams, the patient population included 54 (72%) males and 21 (28%) females, ranging in age from 24 to 87. The mean age for the sample population was 52.5 with a median age of 51. The most frequent presenting complaints included chest pain (64%), shortness of breath (17%), palpitations (5%), and syncope (4%). The most common indication for obtaining a point-of-care echocardiogram was chest pain (47%), followed by “other abnormal clinical finding” (25%), and shortness of breath (9%) (Table 1). Fifty-eight (77%) patients were admitted and 17 (23%) were discharged from the ED. Comprehensive echocardiograms were performed on 40 (53%) of the patients and 12 (16%) underwent cardiac catheterization. Of included subjects, 29 (39%) patients were diagnosed with ACS at discharge. One patient died during hospitalization in the catheterization laboratory, and two patients died within 30 days of admission.

Of 75 included exams, 16 (21%) were positive for myocardial strain, of which 11 (69%) were performed by experienced operators. The characteristics of the 16 positive STE studies as compared to all 75 included studies are presented in Table 2. Compared with comprehensive echocardiography, POC STE had 35% sensitivity, 70% specificity, 46% positive predictive value (PPV), and 59% negative predictive value (NPV).

Table 2
Characteristics of all included studies and positive STE studies.

Results	All included studies ($n = 75$)	Positive STE studies ($n = 16$)
Hospital admission	58 (77%)	16 (100%)
Discharge from the ED	17 (23%)	0
Comprehensive echocardiogram	40 (53%)	13 (81%)
Cardiac catheterization	12 (16%)	3 (19%)
Positive ED troponin	36 (48%)	12 (75%)
WMA on comprehensive echo	17 (23%)	6 (46%)
PCI or >70% stenotic lesion	7 (0.09%)	3 (19%)
Final diagnosis of ACS	29 (39%)	12 (75%)
Death during admission	1 (0.01%)	1 (0.01%)
Death within 30 days	2 (0.03%)	1 (0.01%)

Table 3
Speckle tracking echocardiography identification of patients with WMA.

Parameter	Estimated value	95% confidence interval
Compared to comprehensive echocardiogram		
Sensitivity	0.35	0.15–0.61
Specificity	0.70	0.47–0.86
PPV	0.46	0.20–0.74
NPV	0.59	0.39–0.77
Speckle tracking echocardiography identification of patients with ACS		
Sensitivity	0.29	0.17–0.46
Specificity	0.88	0.72–0.96
PPV	0.75	0.47–0.92
NPV	0.51	0.38–0.64

WMA = wall motion abnormality.
ACS = acute coronary syndrome [positive troponin, unstable angina, PCI or > 70% stenosis at cardiac catheterization].
PPV = Positive Predictive Value.
NPV = Negative Predictive Value.

Compared with formal diagnosis of ACS, POC STE had 29% sensitivity, 88% specificity, 75% positive predictive value (PPV), and 51% negative predictive value (NPV). Scans performed by experienced operators had a higher PPV when compared to comprehensive echocardiography (59% vs. 46%) and formal diagnosis of ACS (82% vs. 75%) (Table 3). Specificity of STE was also higher (80% vs. 70%) when performed by experienced operators as compared to comprehensive echocardiography.

All 75 reviewed charts had an interpretation of the point-of-care echocardiogram in the medical record by ED faculty, and of these 54 (72%) specifically discussed the results of the echocardiogram in their freeform paragraph of medical decision making.

4. Discussion

This study was designed to evaluate the feasibility of strain analysis STE as an adjunct to standard point-of-care echocardiography performed by ED providers. To obtain echocardiographic views considered adequate to detect myocardial strain, high-quality gray-scale images are paramount. STE is highly-operator dependent, and most EPs without ultrasound fellowship training may have difficulty obtaining adequate views to perform strain analysis. This review, however, suggests that experienced ED sonographers are often able to obtain adequate echocardiographic images to perform STE.

Prior studies have shown that STE has a high sensitivity and specificity when performed by Cardiologists in the ED. Dahlslett et al. found that the use of global myocardial strain by echocardiography in the ED may improve the early identification of patients without significant coronary occlusion [7]. Caspar et al. observed that strain echocardiography was superior to high-sensitivity troponins and ECG to identify patients with CAD [6]. Our results suggest that STE performed by EPs in the ED is not yet sensitive enough to detect which patients presenting with clinical concern for ACS have significant coronary disease. When compared to criterion standard diagnostic tests (comprehensive echocardiography, cTn-T assay, and cardiac catheterization), the overall accuracy was low. The specificity and PPV improve, however, when STE is performed by experienced ED sonographers. This study supports STE as part of an ultrasound fellowship curriculum, under supervision by an experienced faculty sonographer. We do not yet recommend that STE be used as a mainstream tool by residents or other non-expert ultrasound users to make clinical decisions without supervision.

From our data, we cannot determine whether STE changed ED providers' clinical decision making. It is important to note, however, that 88% of providers in the ED discussed the findings of a positive STE in the medical decision-making portion of their note. Data does suggest that EPs had significant concern for coronary occlusion in the patients who underwent STE for clinical purposes, as a high percentage of our study population were admitted (77%), and almost half were diagnosed with ACS. Of the 16 patients with positive STE studies, all were admitted, 11 had NSTEMI, and 3 were found to have significant coronary occlusion in the catheterization laboratory. One patient among those with positive STE died during hospitalization in the catheterization laboratory, and another died within 30 days of admission. These numbers suggest that STE was used by EPs to evaluate patients with high clinical suspicion for acute coronary syndrome.

4.1. Limitations

Limitations of this study may have contributed to the low preliminary accuracy of STE. This is a small retrospective analysis of an imaging technology that is not yet routinely used for clinical management in the ED. Our sample size was constrained, as few total studies had been performed. As clinical feasibility was our primary interest, we only included studies with documented interpretations by ED faculty and transmitted to the PACS system, and excluded the STE studies performed only for educational purposes. In the small cohort of included studies, only 16% of our patients underwent cardiac catheterization and 53% patients had a comprehensive echocardiogram after admission.

STE was performed at the bedside in the ED, and our analysis did not include the time between our point-of-care echocardiogram and the comprehensive echocardiogram. Acute coronary syndromes are dynamic, and events such as plaque rupture, thromboses, or reperfusion may have occurred after STE. In their report, Eek et al. emphasized that regional systolic function likely changes during the first days after acute coronary occlusion [2]. In addition, a subset of patients diagnosed with ACS in the ED were treated with potent therapies. Our subjects were treated at the discretion of the ED physician or Cardiologist, and 44% were administered heparin, clopidogrel, or both prior to admission. There may have been recovery of myocardial tissue and changes in myocardial strain patterns prior to admission echocardiogram.

Acute coronary occlusion may progress or regress over time. Resolution or worsening secondary to time and/or treatment may have potentially affected the presence of significant occlusion at catheterization. To address this limitation, studies by Grenne et al., Dahlslett et al., and Caspar et al. compared STE to cardiac catheterization performed in all patients within 27 h $\pm$ 18 h, a median of 26 h, and 27 $\pm$ 20 h of admission, respectively [6,7,8]. Although unlikely to have affected the overall results of the study and our comparison to a final diagnosis of ACS, future studies may benefit from only including STE exams performed within a limited time frame prior to criterion standard tests.

For the purposes of this report, only studies with evaluation of at least 2 windows of myocardial strain were considered “adequate.” The current STE literature provides guidelines for strain imaging that recommend at least 6 views, including apical 4-chamber, 2-chamber and 3-chamber for longitudinal strain, and short axis views at the basal, mid and apical levels for measurement of circumferential strain. A minimum of 3 cardiac cycles should be acquired, and images should be obtained at consistent heart rates [4,9,10]. Even experienced operators in our study did not adequately obtain the recommended 6 windows. In an ED setting, 6 strain windows may not be feasible given time constraints and operator variability. A more concise, focused, and straightforward STE protocol needs to be developed and tested for accuracy to accommodate the pace of the EP.

4.2. Areas for future research

At the time of this study, the providers in the ED were using pattern recognition to interpret STE studies rather than defined values for normal myocardial strain. A consensus statement from the American Society of Echocardiography (ASE) and European Association of Echocardiography (EAE) suggests that the lower limits of -18.5% may be normal for global strain [11] Future studies may evaluate the accuracy of EP-performed STE using a defined normal value and the reproducibility among ED sonographers.

There is still a debate as to the most accurate strain parameter to predict acute coronary occlusion.

Grenne et al. found that territorial circumferential strain was superior for very early identification of acute coronary occlusion [7] while others have supported global longitudinal strain [4,9,12]. It is possible that 3 parasternal short axis windows would be sufficient to diagnose a subtle regional WMA. Circumferential territorial strain is calculated in the parasternal short axis (PSAX) views. The PSAX is one of the more easily acquired echocardiographic views for EPs, in contrast to the apical 4-chamber view. For purposes of STE, PSAX is measured in 3 regions: the apex, the mid-ventricle, and the base. It is logical that PSAX may have a higher sensitivity, because ischemia propagates at mid-myocardium from endocardium to epicardium [7]. Since PSAX is typically more easily obtained and reproduced by novice sonographers, future studies may determine if a single PSAX view would be adequate to detect myocardial strain patterns.

Visual detection of subtle WMA by standard 2-D echocardiography is heavily operator dependent. STE technology should theoretically improve WMA detection by eliminating operator subjectivity. Existing STE imaging technology, including our Toshiba Aplio 300, still requires the operator to obtain near-perfect images and manually trace the walls of the myocardium. As this study illustrates, current STE has not yet improved operator-dependency, and there is substantial opportunity for further software automation.

5. Conclusions

STE is a feasible diagnostic adjunct to standard echocardiography, cTn-T assay, and ECG in the ED. Although our limited study showed STE performed by EPs is not yet sensitive enough for detecting ACS, the PPV and sensitivity improved when performed by experienced ED sonographers. It is a valuable addition to an Emergency Ultrasound Fellowship curriculum, and the spectrum of potential clinical applications should be further studied and developed by ED sonographers. With advancements in imaging software and EP user training, STE may soon become a realistic ED point-of-care diagnostic tool for acute coronary occlusion and other emergent cardiac pathologies.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2018.08.074.

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