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FOCUS may detects wall motion abnormalities in patients with ACS, A retrospective study

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ABSTRACT

Background: Chest pain is a common presentation to the Emergency Department (ED) with roughly 6 million visits a year. The primary diagnostic modality for the identification of acute coronary syndrome (ACS) is the electrocardiogram (ECG), which is used to screen for electrocardiographic findings representing acute coronary occlusion. It is known that the ischemia generated by an acutely occluded coronary vessel generates a wall motion abnormality which can be visualized by echocardiogram; however, emergency physician-performed focused cardiac ultrasound (FOCUS) currently does not have a formal role in the diagnosis of OMI within the emergency department.

Purpose: We sought to define the characteristics of FOCUS performed by emergency physicians of variable training levels in the identification of RWMA in patients presenting to the emergency department with high suspicion for ACS before undergoing cardiac catheterization or formal echocardiography. We also explored whether RWMA was associated with OMI in these patients.

Methods: We performed a structured, retrospective review of adult patients presenting to a large, academic, tertiary care center with suspected ACS from July 1st, 2019, and October 24th, 2020. Patients were included if they underwent FOCUS in the ED during the time-period above for suspected ACS looking for RWMA and FOCUS images were stored and reviewable in our middleware software. The primary outcome was the accuracy, sensitivity, and specificity of FOCUS compared to formal echocardiography for the detection of RWMA. Secondary outcomes were sensitivity of FOCUS compared to formal echocardiography for detection of RWMA in patients with and without cardiac catheterization proven OMI and sensitivity and specificity of FOCUS operators based on training.

Results: FOCUS for RWMA performed by emergency physicians had a sensitivity of 94% (95% CI, 82–98), specificity 35% (95% CI, 15–61), and overall accuracy of 78% (95% CI, 66–87). Of all subjects, 82% underwent urgent or emergency coronary angiography, of which 71% had OMI at the time of coronary angiography of the procedure. FOCUS identified RWMA in 87% of patients with coronary angiography proven OMI. Residents (PGY-1 - PGY-3) ($n = 31$) were able to detect RWMA with a sensitivity of 86% (95% CI, 64–96), a specificity of 56% (95% CI, 23–85%), and an accuracy of 77 (95% CI, 58–90%). Emergency ultrasound fellows and attendings ($n = 34$) were able to detect RWMA with a sensitivity of 85% (95% CI, 64–95%), a specificity of 75% (95% CI, 36–96%), and an accuracy of 82% (95% CI, 65–93%).

Conclusions: Our retrospective study concludes FOCUS performed by emergency physicians may be used to detect RWMA in patients with high concern for acute coronary syndrome. This may have its greatest utility in patients presenting without STEMI where the ECG is felt to be equivocal, but the clinician has high concern for OMI, in which the presence of RWMA might result in emergent cath lab activation, though this requires further study. The presence of RWMA in such cases may help to rule in OMI as a cause; however, the absence of RWMA should exclude OMI. Further research is necessary to confirm these findings.

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Abbreviations: ACS, Acute coronary syndrome; ED, Emergency Department; EP, Emergency physician; FOCUS, Focused cardiac ultrasound; LV, Left ventricle; RWMA, Regional wall motion abnormality; OMI, Occlusion myocardial infarction; STEMI, ST elevation myocardial infarction.

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1. Introduction

Chest pain is a common presentation to the Emergency Department (ED) with roughly 6 million visits a year [1]. It is important for ED physicians to be able to discern those presenting with chest pain caused by cardiovascular disease as it is the number one leading cause of death in the United States and responsible for over 17 million deaths worldwide annually [2]. The primary diagnostic modality for the identification of acute coronary syndrome (ACS) is the electrocardiogram (ECG), which is used to screen for electrocardiographic findings representing acute coronary occlusion. Screening for the presence of acute occlusion myocardial infarction (OMI) is essential as the management differs greatly from those with nonocclusion myocardial infarction (NOMI), namely in the form of reperfusion therapy [3-5]. It is known that the ischemia generated by an acutely occluded coronary vessel generates a wall motion abnormality which can be visualized by echocardiogram; however, emergency physician-performed focused cardiac ultrasound (FOCUS) currently does not have a formal role in the diagnosis of OMI within the Emergency Department [6].

Early work has demonstrated that echocardiograms can be used to identify regional wall motion abnormalities (RWMA) in the Emergency Department when performed by cardiologists [7,8]. More recently, however, point-of-care ultrasound performed by emergency physicians has shown promise in the ability to detect RWMA in hospitalized patients who presented with STEMI or non-STEMI [9,10].

To our knowledge, there are no studies examining the accuracy of (FOCUS) in the Emergency Department for the identification of RWMA in those with and without occlusion myocardial infarction (OMI) during the initial moments in the Emergency Department.

We sought to define the characteristics of FOCUS performed by emergency physicians of variable training levels in the identification of RWMA in patients presenting to the Emergency Department with high suspicion for ACS before undergoing cardiac catheterization or formal echocardiography. We also explored whether RWMA was associated with OMI in these patients.

2. Methods

2.1. Study design

We performed a structured, retrospective review of collected data consistent with the recommended methodology of Kaji et al. [11] Our study followed the Strengthening of Reporting Observational Studies in Epidemiology (STROBE) reporting guidelines for cross-sectional studies (http://www.equator-network.org/reporting-guidelines/strobe/). As this was a study on a diagnostic test, our study followed the Standards for the Reporting of Diagnostic accuracy (STARD) guidelines. Because of the retrospective design, we received IRB approval with waiver of informed consent.

2.2. Setting and population

Adult patients presenting to a large, academic, tertiary care center with suspected ACS from July 1st, 2019, and October 24th, 2020 were screened for inclusion in this study. Patients were included if they were > 17 years old, had a high suspicion of ACS, and underwent FOCUS in the ED and formal echocardiography during the index visit. The study site is a large, academic medical center with approximately 100,000 annual adults visits per year. The study site is also an accredited Chest Pain Center. Patients were included if they underwent FOCUS in the ED during the time-period above for suspected ACS looking for RWMA and FOCUS images were stored and reviewable in our middleware software QPathE (Vancouver, CA).

2.3. Outcomes

The primary outcome was the accuracy, sensitivity, and specificity of FOCUS compared to formal echocardiography for the detection of RWMA. The FOCUS operator's assessment was considered truly positive for a RWMA if the operator indicated there was a wall motion abnormality in at least one LV wall that aligned with the interpretation on the formal echocardiogram or which aligned with the walls affected by the specific anatomic location of an occlusion found on cardiac catheterization (TIMI flow 0–1). Formal echocardiography was defined as echocardiography performed by a trained echo technician or cardiology fellow and interpreted by a cardiology attending. Secondary outcomes were A) sensitivity of FOCUS compared to formal echocardiography for detection of RWMA in patients with cardiac catheterization proven OMI and B) sensitivity of ED cardiac FOCUS compared to formal echocardiography for detection of RWMA in patients without OMI and C) sensitivity and specificity of FOCUS operators based on level of training. We calculated the sensitivity and specificity of FOCUS in identifying RWMA and OMI using formal echocardiography and catheterization as the criterion standards respectively.

2.4. Study protocol and data collection

Patients with ECG findings and clinical features that were highly suspicious for ACS underwent activation of either of two cardiac code activations at our institution: “Code H" or “Heart Alert.” At our institution, Code H and Heart Alerts are more direct and simplified systems to provide emergency revascularization to patients with concern for OMI by history, physical, and ECG criteria.

A “Code H" is activated when a patient, presents with signs and symptoms concerning for ACS and has an accompanying ECG with morphology meeting STEMI criteria. This results in immediate activation of the cath lab's team (e.g., interventional cardiologist, cath lab nurse, cath lab technician, etc.). “Heart Alert” is classified as a patient with symptoms of ACS and has an accompanying ECG with morphology concerning for OMI but does not meet STEMI criteria. In both instances the on-call cardiology fellow presents to the bedside for emergent patient evaluation for potential cardiac catheterization and the patient undergoes FOCUS.

Data extracted from the electronic health records included baseline demographics, chief complaint, medical history, co-morbidities, medications, electrocardiographic findings, laboratory findings (including serum concentrations of cardiac troponin), presence or absence of RWMA on the ED FOCUS or subsequent formal echocardiographs, results of cardiac catheterization (when performed), disposition, and survival. Abstractors were blinded to the outcomes data.

We defined all study data and variables prior to initiating the study and trained our data abstractors using a library of definitions. FOCUS was performed by an emergency physician resident, fellow, or attending. All resident, fellow, and attending level ultrasonographers participated in a 30-min presentation on the identification of RWMAs prior to performing FOCUS included in this study. Left ventricular (LV) walls were simplified into: anterior, inferior, lateral, and posterior walls (Fig. 2). Formal echocardiography utilized 17-segment guidelines which FOCUS was performed with parasternal long, parasternal short, apical four chamber and apical 2 chamber views. RWMA was considered positive if one of more regions had an abnormality. We did not assess the number of regions in which there was WMA, nor did we assess the exact region in which the abnormality occurred. On a randomly selected sample of 90% we had an independent observer assess for RWMA. The observer was an ultrasound trained ED faculty member who was blinded to the ED and cardiology interpretations of the echo. This yielded an interrater reliability of 0.66 (95% CI 0.47–0.0.85) consistent with moderate agreement.

Based on available data, we estimated a 90% probability of the presence of RWMA in the Code H population and a 50% probability in the

Heart Alert cohort. We predicted that ED physicians would be able to identify 80% of RWMA on FOCUS. Therefore, we estimated the need for 62 FOCUS studies with RWMA; that is, 70 Code H studies and 124 Heart Alert Studies. Our study, however, was halted due to the start of the COVID-19 pandemic before our *a prior* targets were achieved.

2.5. Data analysis

Descriptive statistics were used to summarize the data. Binary and categorical data were summarized as numbers and percentages while continuous data were summarized using means and standard deviations (SD) and/or medians and interquartile ranges (IQR). Sensitivities, specificities, positive predictive values (PPV) and negative predictive values (NPV) were calculated along with their 95% confidence intervals (95% CI) using two by two contingency tables. Statistical analysis was completed using SPSS version 28.

3. Results

3.1. Study population

Between July 1st, 2019, and October 24th, 2020, we identified a group of 494 patients that were considered high risk for ACS and activated the "Code H" or "Heart Alert" system. Of these 494 patients, 213 underwent FOCUS in the ED. Of these 213 patients' ultrasounds, 76 patients had documented interpretation of the presence or absence of RWMA. Eleven of the 76 cases were excluded as not having formal echocardiography performed for comparison, leaving 65 patients for analysis (Fig. 1). The mean age was 62 years, 35% were female, 76% were white. Additional patient characteristics can be found in Table 1.

Table 1
Patient demographics and clinical characteristics.

	n (%) unless otherwise specified
Total cases	65 (100)
Demographics	
Mean age (SD)	62 (14)
Median age (IQR)	61 (53–73)
Gender	
Male	42 (65)
Female	23 (35)
Race, n (%)	
White	50 (76)
Black	5 (9)
Hispanic	3 (5)
Asian	1 (1)
Other	6 (9)
Medical History	**n (%) unless otherwise specified**
DM	20 (31)
HTN	47 (72)
HLD	37 (57)
Smoking	40 (62)
CHF	12 (18)
CAD	19 (29)
Clinical Characteristics	
Median Time to ED US (IQR) [min]	10 (3–6)
Median Time to Echo (IQR) [min]	952 (59–1356)
Median Time to Catheterization (IQR) [min]	1455 (91–1476)
Underwent Coronary Angiography	53 (82)
Acute Coronary Occlusion on Cardiac Catheterization	46 (71)
Mean peak troponin (SD)	4.48 (7.03)
Median peak troponin (IQR)	1.40 (0.29–6.42)

CAD: Coronary artery disease; CHF: Congestive heart failure; DM: Diabetes mellitus; HLD: Hyperlipidemia; HTN: Hypertension; IQR: Interquartile range; SD: Standard deviation.

3.2. Primary outcomes

Using formal echocardiography as the criterion standard, FOCUS for RWMA performed by emergency physicians had a sensitivity of 94% (95% CI, 82–98), specificity 35% (95% CI, 15–61), and overall accuracy of 78% (95% CI, 66–87) (Table 2). The median (IQR) time to cardiac catheterization from arrival to the ED was 1455 min (91–1476). The median (IQR) time from arrival to formal echocardiogram was 952 min (59–1356).

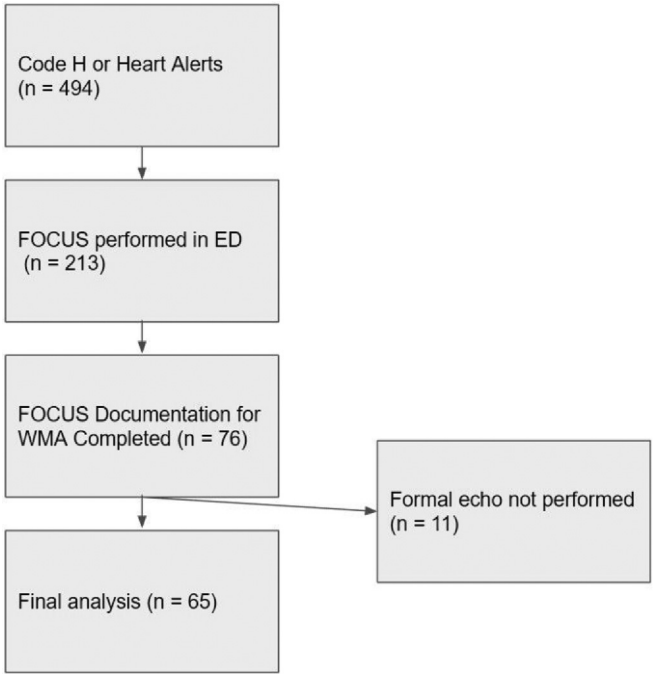

Fig. 1. Subject Selection Flow Chart.

Of all 65 subjects, 82% underwent urgent or emergent coronary angiography, of which 71% had OMI at the time of coronary angiography. FOCUS performed by an operator of any training level identified RWMA in 87%% of patients with coronary angiography proven OMI. Two patients were found to have triple vessel disease and was referred for coronary artery bypass grafting.

Sub-group analysis was performed based on the level of training of the ED providers.

Residents (post graduate years 1–3) ($n = 31$) were able to detect RWMA with a sensitivity of 86% (95% CI, 64–96), a specificity of 56% (95% CI, 23–85%), and an accuracy of 77 (95% CI, 58–90%). Emergency ultrasound fellows and attendings ($n = 34$) were able to detect RWMA with a sensitivity of 85% (95% CI, 64–95%), a specificity of 75% (95% CI, 36–96%), and an accuracy of 82% (95% CI, 65–93%). Performance of FOCUS for RWMA by level of training in Heart Alert and Code H can be found in the supplemental materials.

4. Discussion

Our study on a cohort of patients with high concern for ACS demonstrates that FOCUS operated by emergency physicians may accurately identify RWMA in a high-risk cohort that underwent emergent cardiac catheterization. Moreover, these results are particularly accurate in patients found to have OMI at the time of cardiac catheterization. These data suggest that in a patient presenting with high concern for ACS by history, physical, and ECG, the presence of RWMA should further increase suspicion of OMI. However, the absence of RWMA does not reassure against OMI. These results may have the greatest utility in those

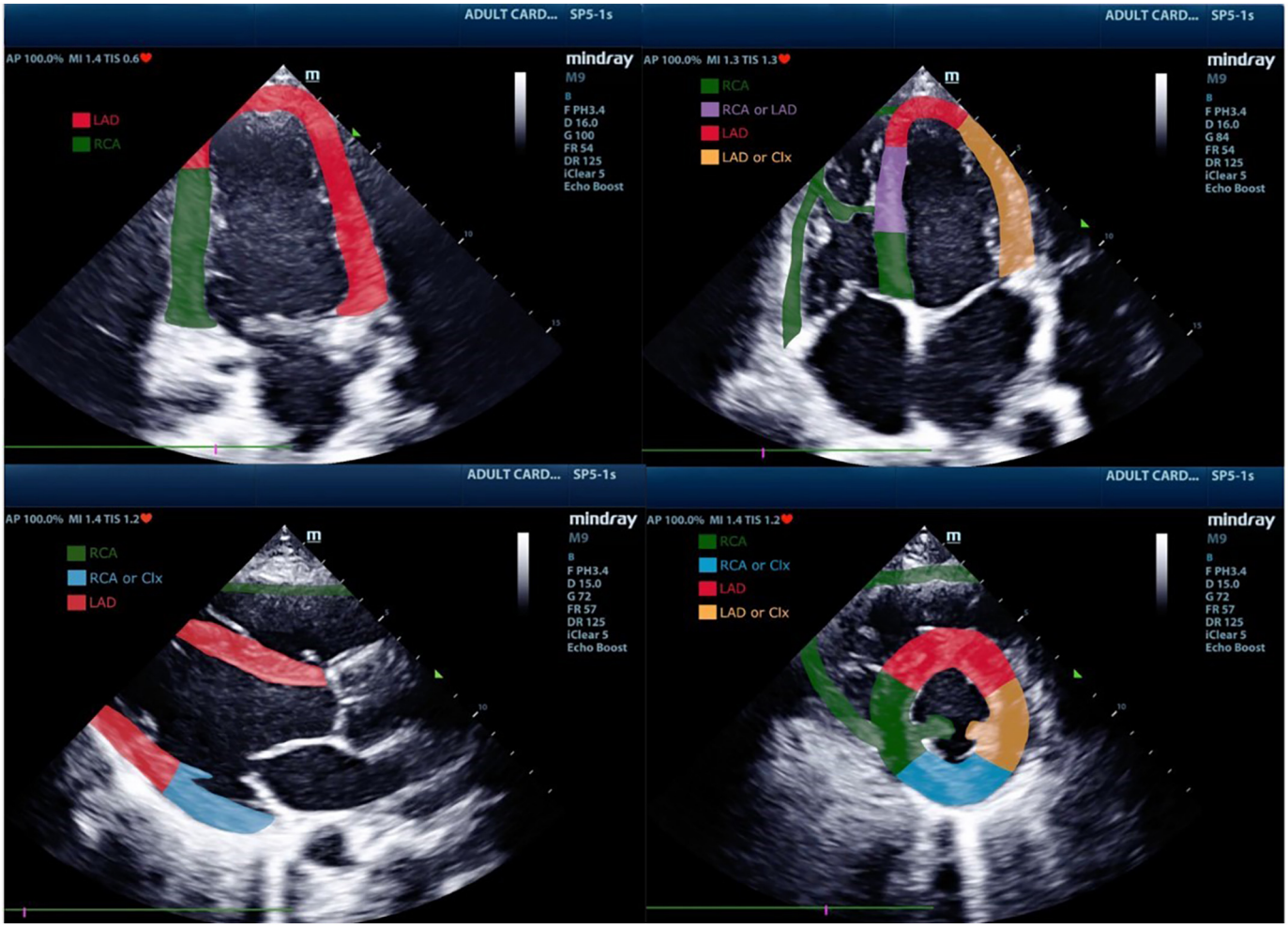

Fig. 2. FOCUS views used for the detection of RWMA.
Clx: Left circumflex; FOCUS: Focused Cardiac Ultrasonography; LAD: Left anterior descending; RCA: Right coronary artery; RWMA: Regional Wall Motion Abnormality.

with OMI that do not meet STEMI criteria. In such cases, diagnostic tests beyond the ECG feature more prominently in the decision of whether to emergently activate the cath lab (e.g., serum troponin levels, ongoing ischemic symptoms, etc.). It is conceivable, therefore, that the presence of RWMA in a cardiac territory that aligns with the cardiac territory by ECG might result in emergent cath lab activation, even if STEMI criteria is not met. Future research is necessary to explore this possibility, however.

Notably, our study was conducted on patients still in the Emergency Department while awaiting cardiology evaluation for emergent reperfusion, thereby reflecting clinical practice (i.e., limited time for views, stress response, inability to position perfectly, etc.). While this may have influenced the results of the echocardiograms rendering them of lesser or suboptimal quality, it renders the results more generalizable and more reflective of current clinical setting.

It is important to note that many conditions may cause regional wall motion abnormalities in the absence of ACS; therefore, our study took a practical approach of examining regional wall motion abnormalities in the setting of cardiac catheterization proven OMI, which is ultimately the cohort EPs are aiming to identify. Another strength of our study is that it included patients that did not meet STEMI criteria but were still considered high risk for ACS. The integration of this population is meaningful in that using ultrasound as an adjunctive test for this group may help to convince both the emergency physician and cardiology team of the degree of concern for OMI when the ECG is felt to be equivocal. This is likely the target population that would benefit from earlier identification of OMI and may influence outcomes, as the current STEMI/NSTEMI paradigm and management algorithms may lead to long delays to cardiac catheterization and increased mortality [3,7,8]. Future studies should investigate the performance characteristics of FOCUS performed by an EP in those with that do not meet STEMI criteria but have changes suggestive of OMI. It is conceivable that in such a study, those with STEMI on pre-hospital ECG may be excluded owing to door-to-balloon time metrics and, in some instances, bypassing of the ED altogether with direct admission to the cath lab. Prior studies on the ability of RWMA to aid in the detection of ACS featured echocardiograms performed by members of the cardiology service rather than emergency

Table 2
FOCUS compared to formal echocardiography for the detection of RWMA.

	Sensitivity	Specificity	PPV	NPV	Accuracy	LR+	LR-
All cases $n = 65$	94 (45/48) (82–98)	35 (6/17) (15–61)	(45/56) 80 (67–89)	67 (6/9) (31–91)	78 (51/65) (66–87)	1.45 (1.01–2.07)	0.18 (0.05–0.63)

FOCUS: Focused Cardiac Ultrasonography; LR: Likelihood ratio; NPV: Negative Predictive Value; PPV: Positive predictive value; RWMA: Regional Wall Motion Abnormality.

physicians [7,8,12]. More recently, Croft et al. demonstrated that emergency medicine trainees are capable of identification of RWMA in the inpatient setting in those present with STEMI criteria on ECG [10]. More, Xu et al. demonstrated that patients with concern for OMI with RWMA on POCUS in the ED were more likely to undergo cardiac catheterization more rapidly than those who did not [13]. However, to our knowledge there has never been a study to examine the question of whether emergency physicians are able to identify RWMA in high risk patients in the Emergency Department prior to cardiac catheterization.

In another recent study, Saglam et al. found that EPs were able to identify RWMA in patients presenting with chest pain and an elevated HEART score without meeting STEMI criteria with a sensitivity of 76.9%, specificity of 92.1% and accuracy of 87.6% as compared with retrospective cardiology interpretation [9]. While these results are important, our study intended to identify those at high risk for OMI and in need for emergent reperfusion therapy despite not necessarily meeting STEMI criteria.

4.1. Study limitations

There are several inherent limitations of our study. The first limitation is the small study population that was terminated due to the onset of the COVID-19 pandemic. Furthermore, it is a retrospective study performed in a single center with a largely affluent, Caucasian population. Due to its retrospective nature, we were unable to standardized protocols which may have impacted the results. Our study also has significant selection bias since only 1/7 who presented as Heart Alert or Code H had a FOCUS in our middle software. This may limit the generalizability of our conclusions. Since FOCUS was not performed in many cases, selection bias is also likely further limiting the external validity. A larger, prospective study is necessary to further explore this question. In addition, our sonographers were not blinded to clinical information including the ECG. This introduces the potential for bias, particularly observer bias when indicating the regional wall affected. However, this is also representative of current clinical practice, where patient presentation and adjunctive tests are synthesized often in parallel.

Another limitation is that we did not look specifically at the amount of FOCUS exams the ED providers performed prior to participating in this study as clinicians with more experience and comfort with FOCUS may be more likely to perform and record ultrasounds and reduce the generalizability of the study. Moreover, the median time from patient arrival to formal echocardiogram was 1071 min. It is customary out our institution for most echocardiograms to be performed after cardiac catheterization on patients at a high risk of ACS. It is conceivable that during this time, RWMA may resolve, particularly in smaller OMI or those that were intervened upon more rapidly, which would artificially lower the accuracy of ED based FOCUS. Future studies might incorporate an echo-boarded cardiologist in the real-time analysis of RWMA for comparison. It is also conceivable that some FOCUS studies were either non-diagnostic or of poor quality and were, therefore, either discarded or never recorded. Such a patient population might be those with higher BMIs or chest wall abnormalities, which might bias these data. Similarly, It is important to note that image acquisition and interpretation are two different skills. If the operator is unable to obtain high quality images, the interpretation may suffer.

Additionally, this patient population may not be generalizable to those with underlying cardiac disease. In such patients (e.g., those with structural heart disease, conduction abnormalities, etc.) abnormal WMA may exist, further limiting the utility of FOCUS in the diagnosis of OMI.

Finally, this study featured a high-risk population for acute coronary occlusion. Patients in this study were taken to cardiac catheterization quickly and had high rates of OMI at the time of cardiac catheterization. Therefore, these results may not be generalizable to low-moderate risk patients for acute coronary syndrome. Furthermore, we did not review the ECGs directly for the presence of STEMI criteria; however, our institutional policy is to activate a Code H only for ECGs that have achieved this threshold. For those with ST changes concerning for OMI without, a Heart Alert is activated.

5. Conclusions

Our retrospective study concludes that FOCUS performed by emergency physicians may be used to detect RWMA in patients with high concern for acute coronary syndrome. This may have its greatest utility in patients presenting without STEMI where the ECG is felt to be equivocal but the clinician has high concern for OMI, in which the presence of RWMA might result in emergent cath lab activation, though this requires further study. The presence of RWMA in such cases may help to rule in OMI as a cause; however, the absence of RWMA should exclude OMI. Further research is necessary to confirm these findings.

Author contributions

AB and MS conceived of concept and design of the project. HCT performed the statistics. LM and MM assisted with training and recruiting. All authors contributed meaningfully to the writing and editing of the manuscript. AB takes responsibility for the manuscript as a whole.

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CRediT authorship contribution statement

Alexander Bracey: Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lyndsay Massey:** Formal analysis, Data curation, Conceptualization. **Andrew Pellet:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **Henry C. Thode:** Formal analysis, Data curation. **Thomas R. Holman:** Writing – review & editing, Writing – original draft. **Adam Singer:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Matthew McClure:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michael Secko:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation.

Declaration of Competing Interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2023.03.056.

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