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Research paper

Utility of rest magnetocardiography in patients presenting to the emergency department with chest pain: A case series on the CardioFlux MCG

Sharon E. Mace [a,*], Margarita Pena [b], David J. Ahee [b], Robert Takla [b]

[a] The Cleveland Clinic, Cleveland, OH, USA
[b] Ascension St. John Hospital, Detroit, MI, USA

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ABSTRACT

Background: Magnetocardiography (MCG) may provide a rapid diagnostic option for patients presenting with chest pain in the emergency department (ED).

Case summaries: This case series presents two instances from a multicenter study, where MCG could have served as a rapid, non-invasive diagnostic tool for chest pain patients. In both cases, multiple high-sensitivity troponin (hsTn) tests yielded incorrect evidence of ischemia. In the first case, multiple positive hsTn tests led to the patient requiring 23 h of observation care, while MCG rapidly ruled out acute coronary syndrome (ACS). In the second case, MCG revealed findings indicative of cardiac ischemia where serial ECGs did not indicate ischemia and serial hsTns were normal. Subsequent cardiac catheterization confirmed 99 % stenosis in the patient's left main and left anterior descending arteries, necessitating coronary artery bypass grafting (CABG).

Conclusion: MCG offers a rapid, painless, non-invasive, radiation free assessment for patients presenting with acute chest pain. Integrating MCG into ED workflows has the potential to improve throughput, reduce the need for subsequent patient observation or inpatient admission, and minimize or eliminate the need for other more expensive non-invasive cardiac testing. MCG avoids some of the problems associated with other methods for diagnosing ischemia. MCG does not involve radiation or the use of pharmacologic agents which have a risk for allergic reactions and anaphylaxis, or the need for an intravenous line. Stress tests are frequently contraindicated or unable to be performed in patients on various medications, may require patient cooperation and in the case of exercise stress tests, the patient's capability to exercise. MCG requires no special patient preparation.

1. Introduction

Chest pain is one of the most common patient presentations to emergency departments (EDs) in the United States and worldwide [1–4]. In the United States, there are over 6.5 million patients presenting to EDs and another 4 million outpatient visits for chest pain each year [2,3].. Rapid and accurate patient assessment is imperative to distinguish between cardiac and non-cardiac origins of chest pain. First-line diagnostic tools for evaluating chest pain in the ED setting include ECG and high sensitivity troponin (hsTn) [2,3]. While the sensitivity for detection of ST elevation myocardial infarction (STEMI) or myocardial injury with ECG and hsTn is excellent, their sensitivity for detection of coronary ischemia remains limited [5,6]. Consequently, these limitations may necessitate further patient observation, and lead to delays in initiating appropriate care and inefficient resource utilization. In such scenarios, the utility of novel diagnostic approaches may improve efficiency as well as diagnostic accuracy.

Magnetocardiography (MCG), is a non-invasive, painless technique, requiring no patient effort or specialized technician, and avoids exposure to radiation. MCG can be performed in under 5 min, and measures the magnetic fields generated by cardiac currents. It is unaffected by body composition and by variations in conductivity which can impede ECG measurements [7,8]. This has emerged as a promising tool for the evaluation of chest pain patients to differentiate coronary ischemia from non-ischemic causes [9]. This case series explores the clinical application of MCG, using the CardioFlux MCG system, as a rapid diagnostic tool in the ED setting. See Fig. 1.

Similar to an ECG, changes in ST segment or T-waves on an MCG may

* Corresponding author.
E-mail address: maces@ccf.org (S.E. Mace).

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Fig. 1. Image of the CardioFlux magnetocardiograph system.

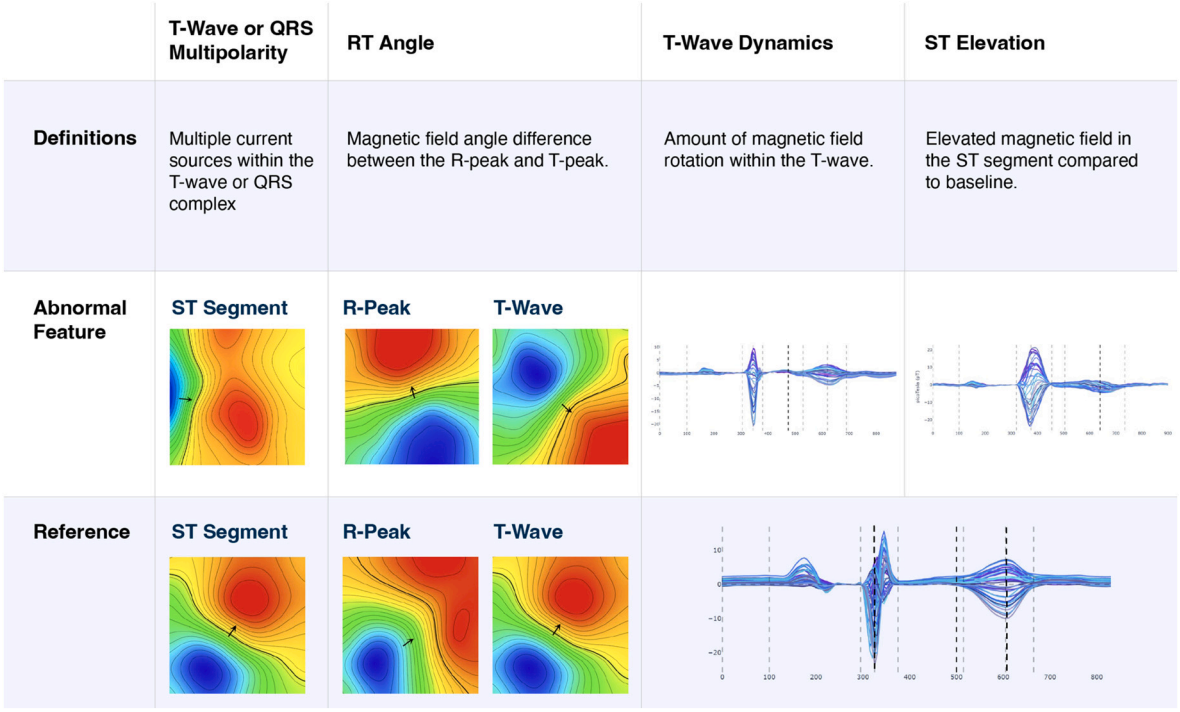

Fig. 2. MCG diagnostic features for cardiac ischemia.

represent coronary ischemia with some important distinctions. A standard 12 lead ECG measures voltage across the chest wall in a two-dimensional plane and is subject to body tissue impedance. In contrast, magnetic waves travel through body tissue to MCG sensors without any attenuation or impedance and are measured in both planar and tangential directions and thus are potentially more sensitive to the detection of coronary ischemia [10]. Fig. 2 demonstrates the MCG diagnostic features of coronary ischemia.

2. Case 1

A 43-year-old male presented to the ED, complaining of chest pain. On presentation, he had a HEART score of 5, with 2 points attributed to ACS-suggestive symptoms in the history, 1 point attributed to risk factors, and 2 points attributed to hsTn. Physical examination revealed an obese patient, experiencing discomfort but not in acute distress. Vital signs were temperature 97.5 °F, heart rate 107, respiratory rate 18, blood pressure 155/91, and oxygen saturation 99 % on room air. The initial ECG exhibited normal sinus rhythm and no acute ischemic abnormalities. See Fig. 3. Standard laboratory tests, including complete blood count and basic metabolic panel, were within normal ranges.

Serial hsTn levels of 43 ng/L, 37 ng/L, and 44 ng/L were abnormal above a normal gender cutoff of 12 ng/L (Roche hsTnT). The patient remained in the ED for 7 h, followed by 23 h of observation. Within 2.5 h of presentation, the patient consented to undergo a non-invasive MCG scan that required no special patient preparation. The test is performed

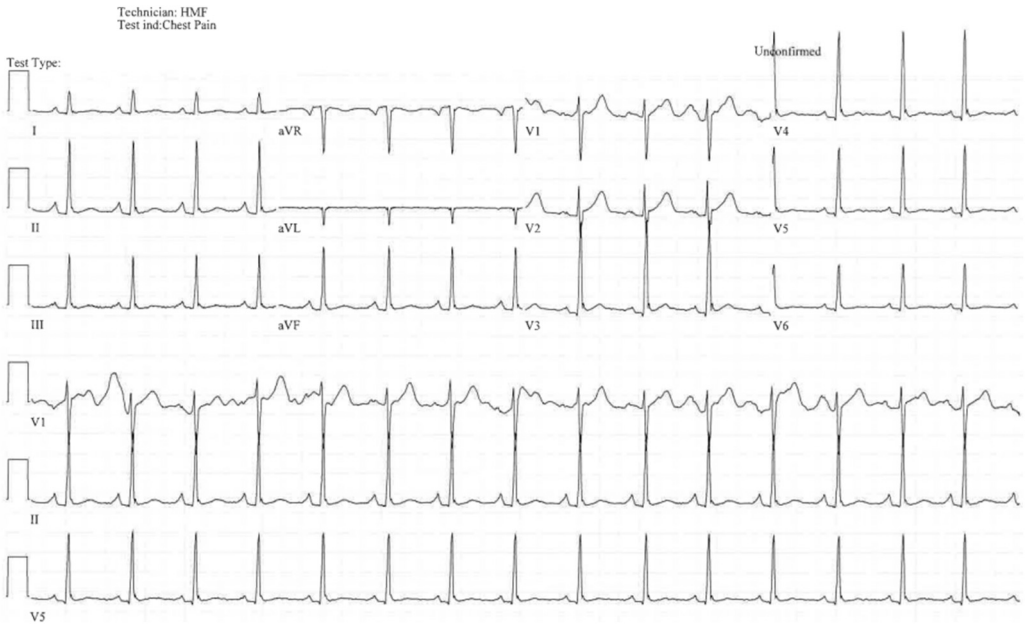

Fig. 3. 12 lead ECG showing NSR at 93 without evidence of ischemia or ectopy. Patient has normal PR, QRS, and QT intervals.

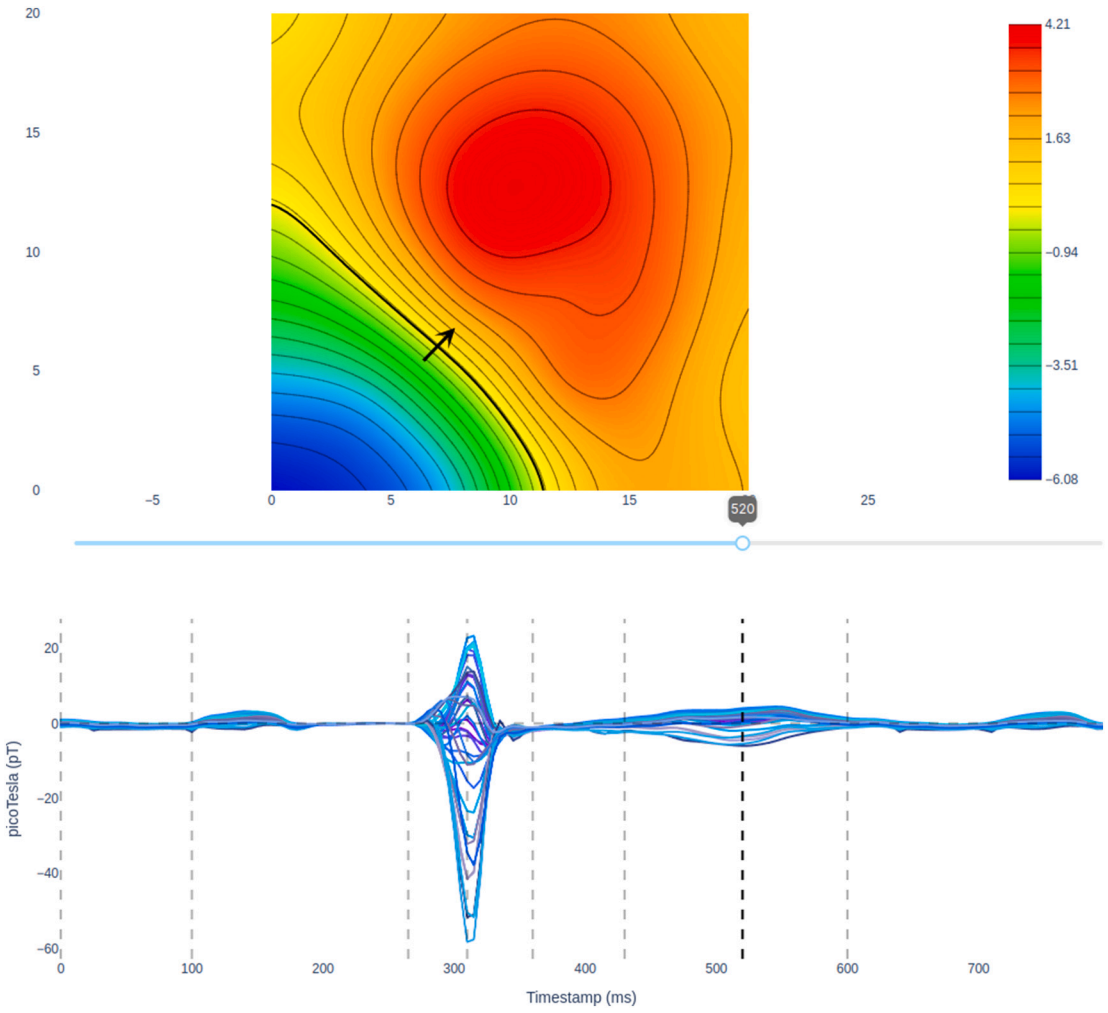

Fig. 4. Patient MCG scan. This MCG demonstrates a normal and stable magnetic wave pattern with normal RT angle, T-Wave dynamics, and without any multi-polarity or significant migration of the negative or positive poles relative to one another in either the ST segment or T-Wave.

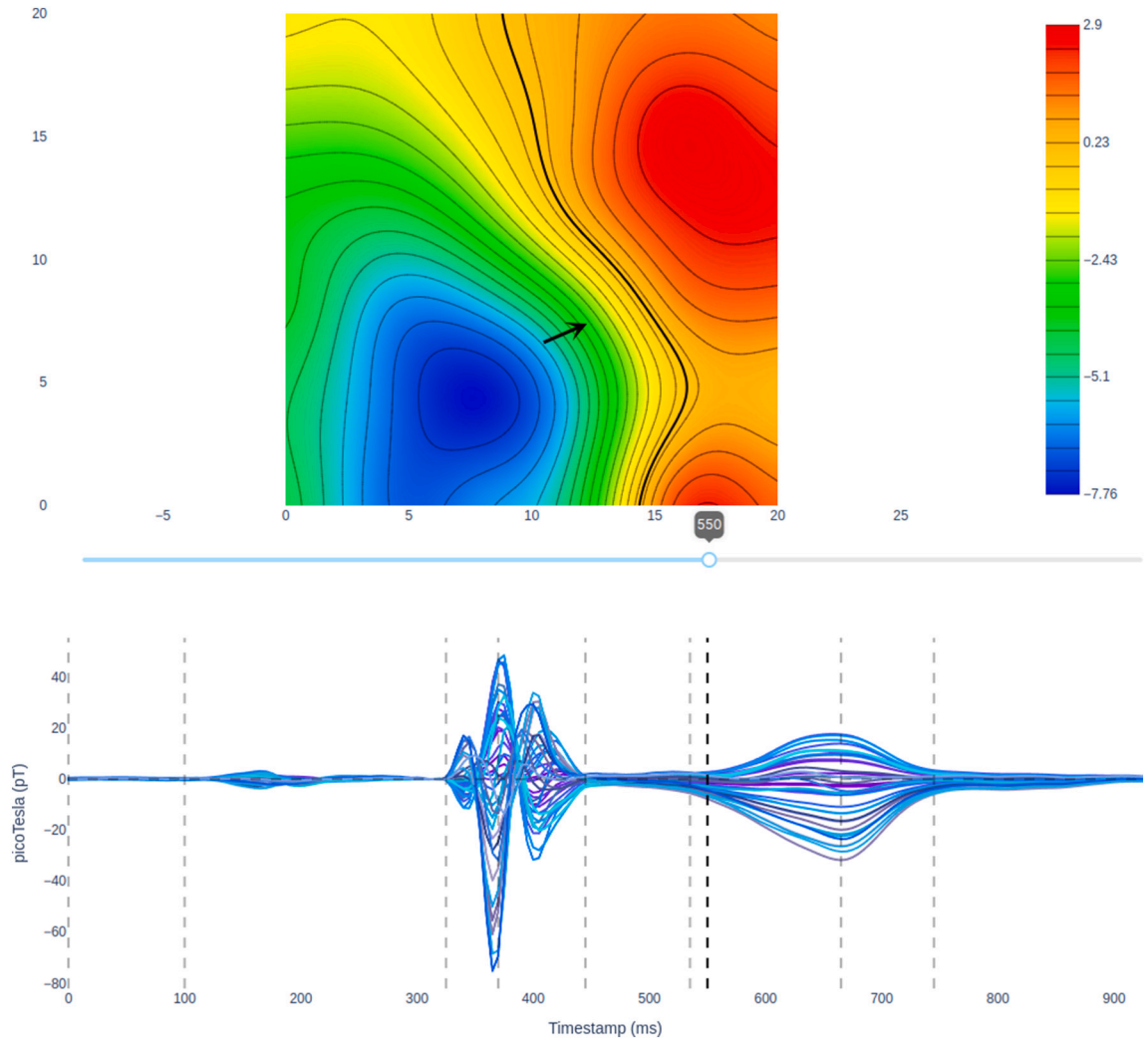

Fig. 5. Patient MCG scan. This MCG scan demonstrates a feature of multipolarity during the T wave. Normal MCG scans will have a single negative (blue) pole and a single positive (red) pole. This MCG, with multipolarity in the positive pole (2 red poles) is consistent with coronary ischemia. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

at rest and was completed in under 5 min. See Fig. 4. The treating clinicians and patient were blinded to the results which were consistent with non-ischemic findings attributing the symptoms to non-cardiac causes. Given the elevated troponins and concern for ACS, clinicians kept the patient under observation, ordering further downstream testing. This is consistent with the current 2021 ACC/AHA guidelines. During this period, an exercise stress test showed no abnormalities, and a subsequent nuclear stress test (myocardial perfusion single-photon emission computerized tomography (SPECT) study) exhibited no evidence of ischemia. The patient's total observation duration extended to 23 h, after which he was discharged with a final diagnosis of atypical chest pain and gastroesophageal reflux disease with esophagitis.

3. Case 2

A 58-year-old male presented to the ED, with acute chest pain as the chief complaint. The patient's medical history included hypertension and hyperlipidemia, for which he was prescribed a daily calcium channel blocker and statin therapy, respectively. He had no history of tobacco use. On admission, he had a HEART score of 4, with 1 point attributed to History, 1 point for ECG changes, 1 point attributed to age, and 1 point attributed to risk factors. Physical examination revealed a mildly overweight patient experiencing discomfort but not in acute distress. Vital signs were temperature 97.3 °F, heart rate 68, respiratory rate 18, blood pressure 146/68, and oxygen saturation 100 % on room air. The initial ECG exhibited sinus bradycardia, incomplete right bundle branch block (RBBB), and nonspecific ST T-wave findings without definitive ischemia. No previous ECGs were available for comparison. Standard laboratory tests, including complete blood count and basic metabolic panel were within normal ranges. High-sensitivity troponin levels of 11 pg/mL and 6 pg/mL remained below a normal gender cutoff of 20 pg/mL (Beckman Coulter Access hs-cTnI). Per guidelines a HEART score of 4 represents an intermediate risk patient, and despite serial negative hS-cTn in this patient which help rule out myocardial injury, coronary ischemia cannot be excluded. As such, ACC/AHA guidelines state such patients may benefit from extended observation, serial monitoring, and additional non-invasive testing. Such testing may include a stress echo or Coronary Computed Tomographic Angiography (CCTA).

Within 2 h of placement in the observation unit, the patient consented to undergo a non-invasive MCG scan that required no special patient preparation and was completed in under 5 min (Fig. 5). The treating clinicians and patient were blinded to the results which were consistent with ACS, attributing the symptoms to cardiac ischemia. While in the observation unit, the patient underwent a repeat ECG, which displayed sinus bradycardia without notable changes compared

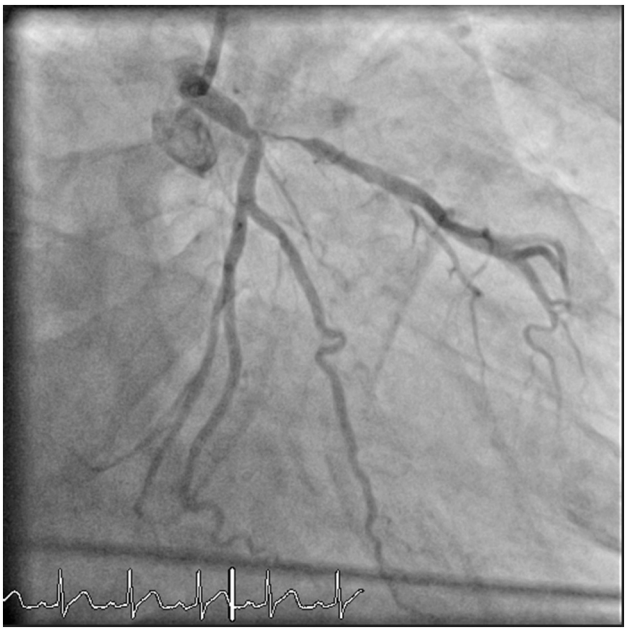

Fig. 6. Angiograms illustrating stenosis in the LAD and LMCA. One can see the stenosis in the LMCA proximal to the bifurcation and the severe stenosis in the LAD.

to the initial ECG. A stress echocardiogram ordered by the treating clinicians revealed substantial wall motion abnormalities in the left anterior descending artery (LAD) region with an ejection fraction of 45 %, moderately reduced right ventricular systolic function, mild mitral valve regurgitation, and trace tricuspid regurgitation. Due to the abnormal results from the stress echocardiogram, the patient was referred for cardiac catheterization. The catheterization results confirmed 99 % stenosis in the left anterior descending (LAD) and left main coronary artery (LMCA), necessitating coronary artery bypass grafting (CABG) (Fig. 6). Six days following presentation, the patient was discharged status post CABG, with additional diagnoses of ventricular fibrillation, coronary artery disease, and heart failure with reduced ejection fraction. The patient spent 4 h in the ED, followed by 20.5 h in the observation unit, and a subsequent 5-day hospital admission.

4. Discussion

Case 1 underscores the significance of rapid diagnostic tools for patients presenting with chest pain symptoms. While existing non-invasive modalities can provide additional information to diagnose or rule out coronary ischemia, such tests often require 23 h or more to derive that information. During the observation period, this patient underwent three hsTn tests, an exercise stress test, and a nuclear stress test. A CCTA could have been performed in the ED, but this would also require additional time for beta blockade as the patient had a heart rate of 107. CCTA does provide anatomical information. However, the use of CT-Fractional Flow Reserve (CT-FFR) may be needed to provide functional assessment if there is evidence of coronary stenosis in an intermediate range, typically 30–70 %, to determine if the stenosis is physiologically significant. This case demonstrates the utility of MCG as a non-invasive, non-nuclear modality to rapidly rule out ACS, offering potential benefits in terms of radiation avoidance, accelerated diagnosis, improved ED throughput and minimizing overcrowding/boarding, leading to reduced healthcare costs.

Case 2 emphasizes the importance of both clinical assessments coupled with diagnostic tools and guideline recommendations for intermediate risk chest pain patients where ECG and hsTn fail to identify coronary ischemia. Conventional care required 24.5 h to ascertain that the patient's symptoms were due to ACS. During this time, the patient had two negative hsTn tests and two negative ECGs before the conclusive positive stress echocardiography test. This case illustrates the use of MCG as a non-invasive modality for ACS diagnosis, potentially expediting diagnosis and treatment in these patients.

While existing non-invasive modalities such as CCTA and stress tests help identify or rule out patients with coronary ischemia, MCG offers additional potential benefits for the ED, the healthcare system and more importantly, for the patient. The integration of MCG into the ED workflow holds the potential to streamline patient evaluation, reduce or eliminate further observation or admission, and expedite the initiation of medically appropriate therapies. This should lead to a decrease in ED length of stay and improvement in ED turnaround times. Cost savings, and avoidance of an expensive, lengthy inpatient admission or an observation unit stay would likely open more inpatient and observation unit beds, thus benefiting the healthcare system. Benefits for the patient include avoidance of radiation, no need for exercise, less time needed for testing, and no need for an intravenous line, thereby, avoiding the pain and potential risks of a needlestick (as required for pharmacologic stress testing).

5. Conclusion

This case series underscores the potential utility of magnetocardiography using the CardioFlux system in evaluating patients presenting to the ED with chest pain. These cases illustrate diverse clinical scenarios where MCG can significantly impact patient care by arriving at a diagnosis to either rule in or rule out coronary ischemia significantly faster than conventional methods without radiation, medication or need for specialized personnel. More importantly, the ability to reduce observation unit admissions, ED boarding hours and overcrowding should decrease health care costs and achieve a significant positive impact on our health care system.

CRediT authorship contribution statement

Sharon E. Mace: Writing – original draft, Writing – review & editing. **Margarita Pena:** Writing – review & editing. **David J. Ahee:** Writing – review & editing. **Robert Takla:** Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: RT is the Chief Medical Officer for Genetesis, Inc.

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