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Prehospital ECG with ST-depression and T-wave Inversion are Associated with New Onset Heart Failure in Individuals Transported by Ambulance for Suspected Acute Coronary Syndrome

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Abstract

Background: Prehospital electrocardiogram(s) (ECG) can improve early detection of acute coronary syndrome (ST-segment elevation myocardial infarction [STEMI], non-STEMI, and unstable angina) and inform prehospital activation of cardiac catheterization lab; thus, reducing total ischemic time and improving patient outcomes. Less is known, however, about the association of prehospital ECG ischemic findings and long term adverse clinical events. With this in mind, this study was designed to examine the: 1) frequency of prehospital ECGs for acute myocardial ischemia (ST-elevation, ST-depression, and/or T-wave inversion); and, 2) whether any of these specific ECG features are associated with adverse clinical events within 30 day of initial presentation to the emergency department (ED).

Methods: We included consecutive patients ≥ 21 years during a five-year period (2013–2017), who were transported by ambulance to the ED with non-traumatic chest pain and/or anginal equivalent(s) and had a prehospital 12-lead ECG. Two cardiologists (LG, EC), blinded to clinical data, interpreted the 12-lead ECGs applying current guideline based ischemia criteria. Adverse clinical events, return to ED, and rehospitalization evaluated at 30-days.

Results: We identified 3,646 patients (mean age, 59.7 years ±15.7; 45% female) with ECGs, of which N=3,587 had data on the three ischemic markers of interest. Of these, 1762 (49.1%) had

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ECG evidence of ischemia. In adjusted logistic regression models, those with T-wave inversion had a higher odds (OR=1.59) of new onset heart failure, while ST-elevation was associated with lower odds (OR=0.69). Patients with ST-depression had higher odds of new onset heart failure and death within 30 days (OR=1.29, 1.49 respectively), but this association attenuated after controlling for other ECG features.

Conclusions: ST-depression and/or T-wave inversion are independent predictors of new onset heart failure, within 30 days of initial ED presentation. Our study in a large cohort of patients, suggests that using ECG ST-elevation alone may not capture patients with ischemia who may benefit from aggressive anti-ischemic therapies to reduce myocardial damage with resultant heart failure.

Keywords

prehospital electrocardiography; acute coronary syndrome; heart failure

Introduction

Current American Heart Association (AHA) guidelines recommend the acquisition of a prehospital electrocardiogram (ECG) for individuals with symptoms suggestive of acute coronary syndrome (ACS).[1] This would include individuals activating 9-1-1 for non-traumatic chest pain, shortness of breath, radiating pain to the arm or jaw, nausea, cold sweat, or lightheadedness. A prehospital ECG, which is non-invasive and inexpensive, has the potential to inform early clinical decision making, such as bypassing the closest hospital for a more distant one that offers definitive cardiac care (i.e., percutaneous coronary intervention) [PCI]). Rapid and accurate identification of ACS (i.e., ST-segment elevation myocardial infarction (STEMI), non-STEMI, and unstable angina) is critically important because early and rapid reperfusion (i.e., PCI) is associated with improved patient outcomes.[2,3] Electrocardiographic changes (i.e., ST-elevation, ST-depression, T-wave inversion) may indicate acute myocardial infarction/ischemia and drive clinical decisions about life-saving treatments for ACS patients.[4] Non-invasive risk stratification for decreased adverse health outcomes is a clinical priority. However, most studies examining prehospital ECGs have focused on the early phase of care (i.e., time reduction to PCI). Therefore, less is known about the association of prehospital ECGs with ischemic changes on long-term outcomes.

The purpose of this study was to determine the: 1) frequency of prehospital ECG findings for acute myocardial ischemia (ST-elevation, ST-depression, and/or T-wave inversion) among patients with non-traumatic chest pain and/or anginal equivalent(s) transported by ambulance to the ED; and, 2) whether specific ECG changes are associated with adverse clinical events (i.e., HF, reinfarction, or death), or with return to the ED or rehospitalization, within 30 days of hospital discharge.

Material and Methods

The Institutional Review Board at the University of North Carolina at Chapel Hill (UNC) approved our study. Inclusion criteria included: 1) ≥ 21 years or more of age; 2) activated

'9-1-1' for non-traumatic chest pain/anginal equivalent symptoms (arm, shoulder, jaw pain, shortness of breath, diaphoresis, syncope); 3) transported by ambulance; 4) had at least one recorded prehospital 12-lead ECG with an interpretation by a hospital cardiologist; and 5) had a final hospital diagnosis. The only exclusion criterion was no prehospital 12-lead ECG recorded.

Data were collected through an ongoing healthcare registry at Atrium Health (Charlotte, North Carolina) in partnership with Mecklenburg County Emergency Medical Services (MEDIC). A data use agreement between UNC and MEDIC was obtained in order to acquire the prehospital 12-lead ECG data. Trained research specialists extracted data elements from the hospital system on all patients meeting eligibility criteria. The trained research specialists have > 10 years of experience abstracting medical record data for research, including outcomes. Using a deterministic match approach to ensure the correct patient data were merged, a data linkage expert at Atrium health in consultation with study investigators linked prehospital 12-lead ECGs to hospital data elements. In order for prehospital ECGs to be reliably linked to hospital data elements, the following variables were required: date/time of 9-1-1 call, name, and date of birth. In addition, we collected the following data: EMS characteristics, patient baseline characteristics, clinical presentation, EMS scene time, prehospital ECG interpretation results by two cardiologists blinded to clinical data, laboratory results, cardiac catheterization procedure, final hospital diagnosis, and 30-day outcomes (new onset heart failure [HF], death, reinfarction, return to ED, and/or rehospitalization). Clinicians attending to patients documented clinical outcomes in the medical record. Diagnostic codes from the index emergency department visit, hospitalization, or follow-up clinic visits were used to determine outcomes (e.g., new onset HF). Trained research specialists collected hospital and outcome data from electronic medical records.

Prehospital 12-lead ECGs (Philips Heart Start MRx, Andover MA) were acquired by EMS and interpreted by trained paramedics per routine protocol. For study purposes, two independent reviewers blinded from clinical data analyzed the prehospital 12-lead ECGs. The ECG diagnosis of ACS was based on current guideline definitions (Table 1).[5] Interrater reliability was evaluated between the two reviewers and disagreements were discussed and reconciled by a third interpreter (J.Z.H.) applying the same criteria.

Study data were collected and managed using REDCap (Research Electronic Data Capture) hosted at Atrium Health.[6,7] A unique data linkage key was used to connect prehospital ECGs to hospital data elements. REDCap is a secure, web-based software platform designed to support data capture for research studies that provides: 1) an intuitive interface to ensure validated data capture; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for data integration and interoperability with external source.

We exported the REDCap data to SAS software (version 9.4; SAS Institute, Cary, NC) for statistical analyses and summarized data with descriptive statistics and computed frequencies and proportions. The relationship between ECG features and 30-day follow up adverse clinical outcomes (death, reinfarction, and HF) as well as return to the ED and rehospitalization were first analyzed using bivariate methods (chi-square and Fisher's Exact tests). To explore these relationships further, we fit a logistic model for each ECG feature/ adverse clinical outcome pair that controlled for age, sex, race/ethnicity, relevant medical history variables and ECG confounders (left ventricular hypertrophy [LVH], left bundle branch block [LBBB], ventricular paced, or early repolarization). The medical history variables (all dichotomous) were: hypertension, current smoking, diabetes, prior MI, angina, prior coronary artery bypass graft (CABG), prior PCI, coronary artery disease (CAD), and family history of cardiovascular disease. We report odds ratios and 95% confidence intervals. As an exploratory analysis, we examined whether the associations between ECG factors and outcomes differed between subgroups based on pre-existing medical conditions (hypertension or diabetes). We added the interaction between hypertension and the ECG predictor to each of the main effects models, and examined the ORs for each subgroup in the case where the interaction was significant. The process was repeated for diabetes.

Results

Sample Description

Between the years of 2013–2017, a total of 4,350 individuals met inclusion criteria. Accounting for repeat visits from the same patients, there were a total of 3,646 unique patients in the final dataset (Figure 1), and we used the first visit from patients with more than one. The sample was 45% female, mostly of black (47%) and white (45%) race, with a mean age of 59.7 (±15.7) years (range 21->90) (Table 2). Patients indicated the following cardiac complaints, ordered from most common to least common: chest pain (58.4%), shortness of breath (24.2%), palpitations (13.6%), nausea and/or vomiting (11.2%), diaphoresis (9.1%), and syncope (5.4%). There were 662 (18%) patients with a final hospital diagnosis of ACS (i.e., STEMI, non-ST elevation myocardial infarction [NSTEMI], or unstable angina). During the 30-day follow-up, 1946 (N=1946) individuals were reported to have an adverse clinical event (HF, death, reinfarction), return to ED, or rehospitalization. Specifically, 15.8% (N=566) experienced new onset HF, 3.6% (N=129) death, and 0.36% (N=13) reinfarction. A return to the ED was observed in 34.3% of patients (N=1229), and 13.0% of patients (N=463) were rehospitalized. Adverse clinical events were not mutually exclusive; individuals, therefore, may have encountered more than one.

Prehospital 12-lead findings are summarized in Table 2. Of the 3,587 patients with complete ECG interpretations for all three main ischemic markers (ST-elevation, ST-depression, or T-wave inversion), 1762 (49.1%) had ECG evidence of ischemia on their prehospital 12-lead ECG. Interrater reliability for prehospital ECG interpretation was 91%.

ECG findings and 30-day outcomes

The bivariate models in Table 4 illustrate the unadjusted relationships between ECG features and 30-day outcomes. Patients with ST-depression or T-wave inversion were more likely to experience an adverse clinical event (HF, death, and/or reinfarction) compared to those without these features. These patients were also more likely to be rehospitalized within 30 days. ST-elevation was not associated with any of the adverse clinical outcomes or rehospitalization, but was associated with a lower risk of ED return. We added the interaction between hypertension and each ECG feature to the models in Table 4, and none of them were statistically significant. We added the interactions for diabetes, and all were non-significant except the interaction between t-wave inversion and diabetes in the model predicting death (p=0.03). When we looked at the ORs for the two subgroups (diabetes vs. no diabetes), we found that both were nonsignificant, with the odds of death being slightly lower in those who have t-wave inversion among people with diabetes (OR=0.65, p=0.25), and the odds of death being slightly higher in those who have t-wave inversion among those without diabetes (OR=1.05, p=0.84).

Adjusted logistic regression models for death and HF are given in Table 5. Reinfarction is not included because of the small sample sizes. Adjusted for demographics and medical history (Model 1), many of the relationships in Table 4 held. Individuals with ST-depression had 1.49 times higher odds of reported death within 30-days compared to those without (p=0.038), but the adjusted relationship between death and T-wave inversion did not reach statistical significance (p=0.09). In adjusted logistic regression models, individuals with both ST-depression and T-wave inversion had higher odds of new onset HF (OR=1.29, p=0.01; OR=1.59, p<.0001, respectively). In the adjusted model, ST-elevation was not associated with death, but was associated with a decreased risk of new onset HF (OR=0.65, p=0.001).

To control for potential confounding, we further adjusted for additional ECG features (LVH, LBBB, and early repolarization) as shown in Model 2 in Table 5. Ventricular pacing was removed from the model because it created model instability due to small event numbers. After these adjustments, ST-depression was no longer significantly associated with a higher odds of death or new onset HF, but the other observed relationships remained statistically significant. Non-Hispanic blacks had the highest risk of new onset HF, yet there were no racial differences noted for death.

Discussion

In this study, we evaluated whether ECG indices of myocardial ischemia were associated with adverse outcomes at 30-day follow-up. There were 1762 (49.1%) patients with prehospital ECG evidence of ischemia, and these individuals were at greater risk for adverse outcomes at 30-days compared to those without ECG signs of ischemia. We found that ST-depression and T-wave inversion were associated with new onset HF and that ST-elevation was protective against new onset HF. Our study shows that data obtained from standard 12-lead prehospital ECG improves the ability to identify patients earlier who are at risk for adverse health outcomes at long term follow-up. Earlier risk stratification may help high risk patients by instituting more aggressive treatments earlier. To our knowledge, this is the first study to evaluate the role of ECG indices in predicting adverse outcomes at 30-day follow-up in individuals presenting to the ED with high suspicion for ACS.

30-day outcomes

We found significantly higher proportions of individuals with ST-depression and T-wave inversion had higher incidences of any adverse outcome, including death, compared to those without these ECG indices of myocardial infarction. Higher proportion of individuals with

ECG signs of ST-depression and/or T-wave inversion were rehospitalized within 30 days of index hospitalization.

Our findings are in general agreement with previous studies that report initial ECG findings to be associated with adverse outcomes. Brush and colleagues studied the admission ECG to identify patients who could be safely hospitalized in an intermediate care unit.[8] Individuals with ECG evidence of ischemia were 3–10 times more likely than those without ischemia to experience heart failure, non-sustained ventricular tachycardia, third heart sound, jugular venous distension, cardiogenic shock, conduction disturbances, atrial dysrhythmias, or recurrent chest pain; as well as significantly higher incidences of life-threatening complications (ventricular fibrillation, sustained ventricular tachycardia, or heart block)($p<0.01$). Pelter et al.[9] evaluated 237 individuals hospitalized for myocardial infraction or angina; 39 (17%) had ECG evidence of ischemia. The rate of in-hospital complications (i.e., hypotension, acute MI after admission, abrupt vessel closure after PCI, death) for individuals with ischemia was significantly higher compared to those without ischemia. Individuals with ischemia also had significantly longer hospitalizations compared to those without.[9] In contrast to our study, these prior studies included individuals with confirmed ACS diagnoses.[8,9] More recently, Zègre-Hemsey et al. evaluated individuals presenting to EMS with symptoms of ACS and evaluated adverse hospital outcomes.[10] Individuals with prehospital ECG manifestations of acute myocardial ischemia were over 1.55 times as likely to experience an adverse hospital outcome compared to those without ischemia.[10] In a cohort of chest pain patients transported by ambulance, Rivero and colleagues (2019) found nonspecific repolarization abnormalities in the ST-T segment was prevalent.[11] These patients, moreover, had significantly longer length of hospital stay and greater rates of 30-day MACE. Similar to our findings, prior studies have determined ECG signs of ischemia (ST-elevation, ST-depression, and/or T-wave inversion) to be significantly associated with in-hospital adverse outcomes. Our study, however, determined associations specifically between ST-depression and T-wave inversion, and long-term adverse outcomes (~30 days).

A key finding in our study is the significant association between prehospital ST-depression and T-wave inversion with new onset HF within 30 days of hospital discharge. We also determined significant associations with LBBB and LVF, which supports prior evidence that patients who develop LBBB are at increased risk of HF and sudden cardiac death.[12] Our findings highlight the importance of other ECG markers as early indicators of long-term adverse outcomes. The ECG changes, ST-depression and/or T-wave inversion, are not directly causing ventricular dysfunction. Rather, the ECG changes are likely signs of an acute cardiomyopathy, either due to ischemia or another insult (e.g., hypertensive urgency or drug induced coronary spasm). Interestingly, we found that these ECG changes also portend a high risk of rehospitalization due to heart failure. Our findings are timely because an estimated 6.2 million Americans ≥ 21 years old developed HF (2013–2016) and the prevalence of HF is estimated to increase by 46% in 2030,[13] related to an aging population, prolonged survival related to better treatments, and rising number of risk factors (e.g., hypertension, diabetes, obesity).[14] There is a 50% mortality with HF at 5-years, and adults with advanced heart failure (i.e., the presence of progressive and/or persistent severe signs and symptoms of heart failure despite optimized therapy)[15] have a one year mortality as high as 75%.[16] HF symptom detection remains poor, yet accurate recognition of HF is crucial because of the poor outcomes associated and increasing prevalence and burden on society. Our findings suggest prehospital ECG findings may help improve the detection of HF. Further exploration of the type of ST-depression (horizontal vs upsloping vs down sloping) may help better stratify which are more predictive of future HF.

In contrast to ST-depression and/or T-wave inversion, ST-elevation had a protective effect from new onset HF. We hypothesize this may be related to EMS providers being trained to assess for ST-elevation to help determine bypass of closest hospital for one that offers PCI (i.e., definitive cardiac care). EMS systems across NC train paramedics to interpret prehospital ECGs[17], yet the primary focus of ECG interpretation in EMS has predominantly been on assessing ST-elevation. Prior research suggests paramedics can accurately interpret ECGs for ST-elevation with adequate training.[18–20] Future ECG interpretation training for EMS providers may include more of a focus on other signs of ischemia.

Limitations

Our study has potential limitations that should be considered. First, our study used data collected from an ongoing cardiac registry from a single EMS system. This region has a mature and highly integrated cardiac system of care, which may not be generalizable to other emergency systems. Data variables, moreover, are limited to what is collected in the ongoing registry. For example, we were not able to determine association with echocardiographic findings. We also relied on EMS providers' identification and transcription of individuals' presenting complaints. Due to time sensitivity inherent in the prehospital period, EMS providers have not have always accounted for this appropriately.

Conclusion

Specific indices on prehospital ECGs are associated with long-term outcomes in individuals transported for symptoms suspicious for ACS. ST-depression and T-wave inversion, specifically, are significantly associated with new onset HF. Prehospital ECGs provide important information that may be used to enhance early triage and risk stratification. EMS providers and clinicians can consider integrating specific ECG findings to help assess individuals at risk for developing long-term adverse outcomes such as HF.

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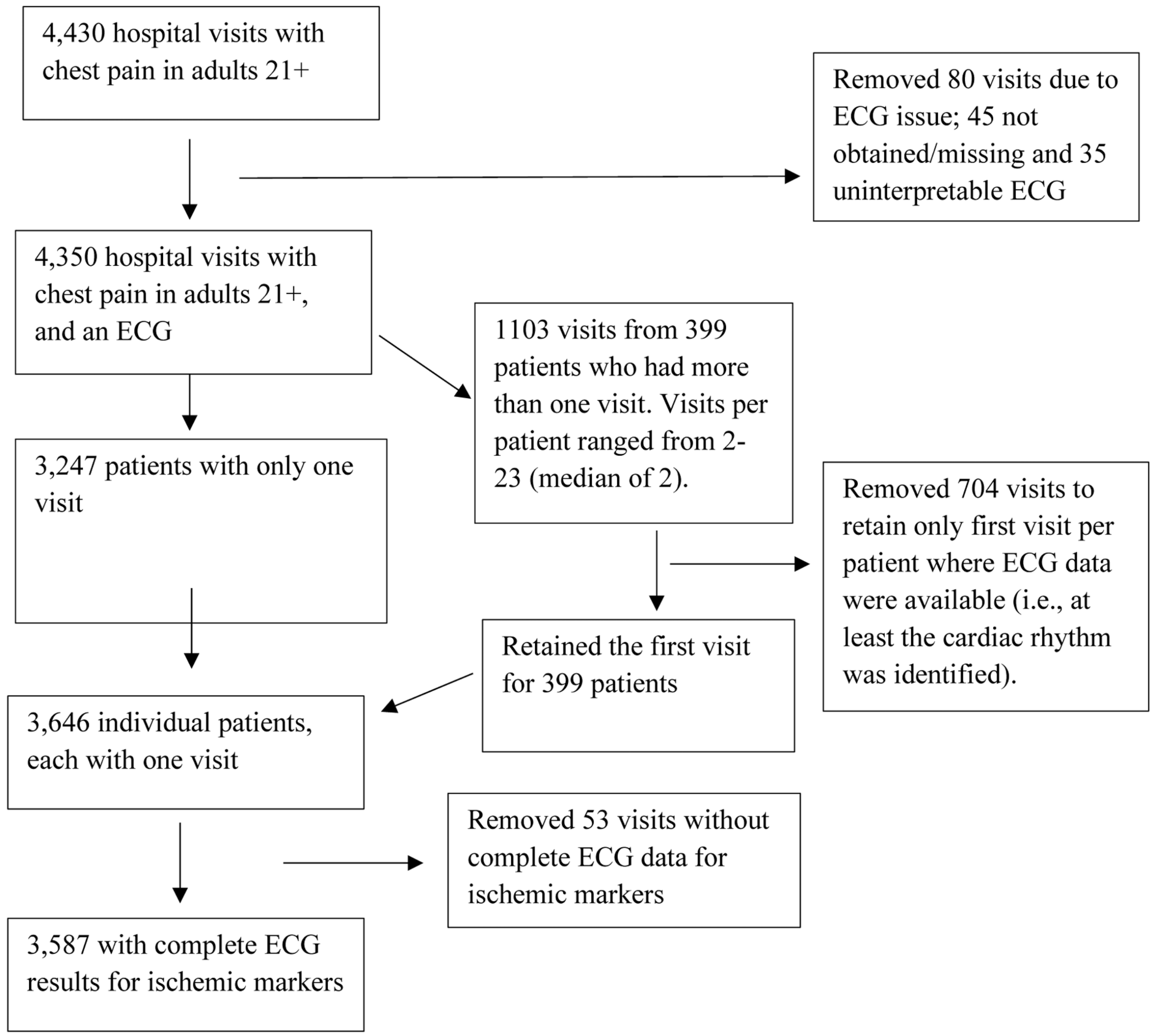

Figure 1.
Sample size flow diagram for patients calling 9-1-1 for non-traumatic chest pain suggestive of acute coronary syndrome transported by ambulance to the emergency department.

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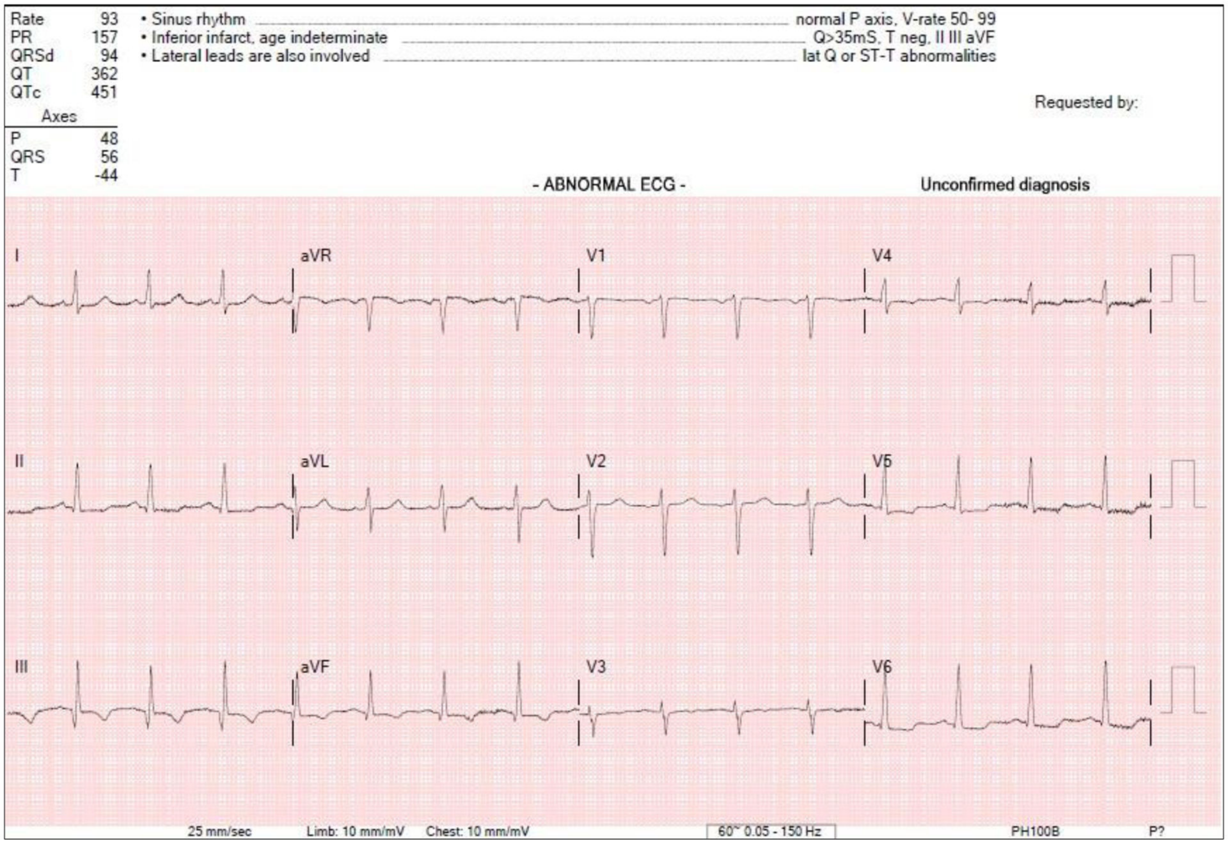

Figure 2.

Case study of ST-depression and T-wave changes and development of heart failure.

A 48-year-old white female called 9-1-1 with complaints of chest pain and shortness of breath. She had a past medical history significant for hypertension, diabetes, and prior inferior MI. Her standard prehospital 12-lead ECG showed normal sinus rhythm at a rate of 93 beats per minute. There was evidence of ST-depression in leads $V_4 – V_6$ and T-wave inversion in leads $V_4 – V_6$, III, and aVF, meeting criteria of ACS per current criteria.[5] The initial troponin was 0.53µg/ml and peak during hospitalization was 0.63µg/ml. The patient had a cardiac catheterization that did not show > 50% vessel occlusion; hence no intervention was done. This patient was ultimately discharged with a final diagnosis of NSTEMI. This patient developed new onset heart failure and rehospitalized within 30 days of hospital discharge.

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Table 1.

Electrocardiographic Manifestations Suggestive of Acute Myocardial Ischemia

ST-elevation: New ST-elevation at the J-point in 2 contiguous leads with the cut-point: ≥1 mm in all leads other than leads $V_2 – V_3$ where the following cut-points apply: ≥ 2 mm in men ≥ 40 years; ≥ 2.5 mm in men < 40 years, or ≥ 1.5 mm in women regardless of age.
ST-depression and T wave changes: New horizontal or downsloping ST-depression ≥ 0.5 mm in 2 contiguous leads and/or T inversion > 1 mm in 2 contiguous leads with prominent R waves or R/S ratio >1.

Thygesen et al., 2018, adapted

Table 2.

Demographic characteristics in 3,646 patients transported by ambulance for suspected ACS.

Patient Characteristic	Mean (SD) or n(%)
Age	59.7 (15.7) years, range 21->90
Sex	
Female	1633(44.8)
Race	
American Indian or Alaska Native	5(0.14)
Asian	36(0.99)
Black or African American	1720(47.2)
White	1631(44.7)
Multiracial	7(0.19)
Unknown	247(6.8)
Ethnicity	
Hispanic	130(3.6)
Non-Hispanic	3350(91.8)
Unknown	166 (4.6)
Primary hospital diagnosis	
Any ACS	662(18.2)
STEMI	452(68.2)
NSTEMI	147(22.2)
Unstable angina	63(9.5)
Non-ACS	2984(81.8)
Outcomes within 30 days	
Any of the three adverse clinical outcomes below	691 (19.0)
Death	137 (3.8)
Reinfarction	13 (0.4)
New onset HF	586 (16.1)
Return to ED	1250 (34.3)
Rehospitalization	474 (13.0)

Each author made significant contributions to the manuscript and provided insights to the revisions. Jessica Zègre-Hemsey conceived of the study idea, made direct contributions to writing the paper, and led the study. Melanie Hogg and Pilar Tochiki extracted hospital data elements and reviewed multiple manuscript drafts. Jamie Crandell conducted statistical analyses, data interpretation, created tables, and reviewed multiple drafts. Len Gettes and Eugene Chung provided expert ECG interpretation and reviewed drafts of the manuscript. Michele Pelter reviewed multiple drafts and provided expertise to the prehospital 12-lead ECG interpretation. Jonathan Studnek and David Pearson provided expert guidance to the conceptualization of the study, manuscript draft recommendations, and ongoing support to conducting research in the prehospital and ED settings. Wayne Rosamond contributed to the overall study conduct, writing of the manuscript drafts, and expertise in EMS systems of care.

This manuscript has not been previously published nor is under consideration for publication elsewhere.

Table 3.

Prehospital 12-lead ECG indices in individuals with non-traumatic chest pain suggestive of acute coronary syndrome transported by ambulance to the emergency department (N=3,646).

Electrocardiographic findings	n(%)
Rhythm	
Normal sinus rhythm	2819(77.3)
Atrial fibrillation/flutter	522(14.3)
Junctional rhythm	47(1.3)
Ventricular paced	62(1.7)
2nd degree heart block	10(0.3)
3rd degree heart block	40(1.1)
SVT	91(2.5)
VT	11(0.3)
Multifocal atrial tachycardia	2(0.1)
PVC	323(8.9)
Other	177(4.9)
QRS morphology	
Normal	2895(79.4)
RBBB	282(7.7)
LBBB	136(3.7)
LAFB	234(6.4)
LPFB	34(0.9)
IVCD	141(3.9)
Early repolarization	182(5.1)
LVH (Cornell voltage criteria)	226(6.3)
LVH with strain	325(9.1)
LVH by other criteria (e.g., Sakolov)	35(0.9)
Prior myocardial infarction location	
Inferior	142(3.9)
Anterior	150(4.1)
Lateral	27(0.7)
Septal	81(2.2)
ECG Feature of acute ischemia	
ST-elevation	923(25.7)
ST-depression	1061(29.5)
T-wave inversion	1126(31.3)
Hyperacute T-wave	28(0.8)
Non-specific ST-T wave	486(13.5)

SVT=supraventricular tachycardia, VT=ventricular tachycardia, PVC=premature ventricular contraction, RBBB=right bundle branch block, LBBB=left bundle branch block, LAFB=left anterior fascicular block, LPFB=left posterior fascicular block, IVCD=intraventricular conduction delay. Due to missing data, total N is less than 3,646 for the following variables: Early repolarization N=3,560, ST-elevation N=3,597, ST-depression N=3,594, T-wave inversion & non-specific ST-T wave N=3,593, Hyperacute T-wave N=3,596.

*Groups are not mutually exclusive.

Table 4.

Association between ECG features and adverse clinical events (death, reinfarction, and new onset HF), return to ED, and rehospitalization reported within 30 days. Counts and percents indicate the prevalence of the outcome among those with/without the ECG feature. (N=3,587)

		Any of the three adverse Clinical outcomes N(%)	Death N(%)	Re-infarction N(%)	New onset HF N(%)	Return to ED N(%)	Re-hospitalization N(%)
Entire Sample	N=3,587	667 (18.9%)	129 (3.6%)	13 (0.36%)	566 (15.8%)	1229 (34.3%)	463 (12.9%)
ECG Features:							
T-wave inversion	No (N=2464)	369 (15%)***	73 (3%)***	5 (0.2%)*	314 (12.7%)***	922 (37.4%)***	297 (12.1%)*
	Yes (N=1123)	298 (26.5%)	56 (5%)	8 (0.7%)	252 (22.4%)	307 (27.3%)	166 (14.8%)
ST-Depression	No (N=2530)	401 (15.9%)***	73 (2.9%)***	4 (0.2%)**	345 (13.6%)***	987 (39%)***	306 (12.1%)*
	Yes (N=1057)	266 (25.2%)	56 (5.3%)	9 (0.9%)	221 (20.9%)	242 (22.9%)	157 (14.9%)
ST-Elevation	No (N=2668)	502 (18.8%)	92 (3.5%)	5 (0.2%)**	433 (16.2%)	996 (37.3%)***	346 (13%)
	Yes (N=919)	165 (18%)	37 (4%)	8 (0.9%)	133 (14.5%)	233 (25.4%)	117 (12.7%)

* p<.05,

** p<.01,

*** p<.001.

p-values are from chi-square tests relating the outcome to the feature. For tests involving reinfarction or ventricular pacing, we used Fisher's Exact test instead of chi-square due to small cell counts. Note: There was a small amount of missing data, so the sample sizes are smaller for early repolarization (N=3,534) and LVH (N=3,540).

Table 5.

Association between ECG ischemia features and adverse clinical events (death, reinfarction, and new onset HF), return to ED, and rehospitalization reported within 30 days. (No models were fit for reinfarction because there were only 13 cases.)

ECG variable	Odds ratio for Death	p-value	Odds ratio for New Onset HF	p-value
Model 1: Adjusted ORs controlling for age, race, gender, medical history				
T-wave inversion	1.39 (0.96, 2.02)	0.09	1.59 (1.31, 1.93)	**<.0001**
ST-Depression	1.49 (1.02, 2.18)	**0.038**	1.29 (1.05, 1.58)	**0.01**
ST-Elevation	1.13 (0.74, 1.73)	0.58	0.68 (0.54, 0.86)	**0.002**
Model 2: Adjusted ORs controlling for age, race, gender, medical history, LBBB, Early repolarization, and LVH.				
T-wave inversion	1.25 (0.83, 1.87)	0.29	1.42 (1.15, 1.74)	**0.0009**
ST-Depression	1.41 (0.94, 2.14)	0.10	1.14 (0.92, 1.42)	0.22
ST-Elevation	1.01 (0.63, 1.60)	0.98	0.65 (0.50, 0.83)	**0.0006**

Note: we had also intended to control for ventricular pacing in Model 2, but the small event numbers in those with ventricular pacing led to model instability, so it was removed.