Title: The Availability of Prior ECGs Improves Paramedic Accuracy in Recognizing ST-Segment Elevation Myocardial Infarction.

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Running Title: Prior ECG Impact on Paramedic STEMI Determination

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Abstract:

Introduction: Early and accurate identification of ST-Elevation Myocardial Infarction (STEMI) by prehospital providers has been shown to significantly improve door to balloon times and improve patient outcomes. Previous studies have shown that paramedic accuracy in reading 12 lead ECGs can range from 86-94%. However, recent studies have demonstrated that accuracy diminishes for the more uncommon STEMI presentations (e.g. lateral). Unlike hospital physicians, paramedics rarely have the ability to review previous ECGs for comparison. Whether or not a prior ECG can improve paramedic accuracy is not known.

Study Hypothesis: The availability of prior ECGs improves paramedic accuracy in ECG interpretation.

Methods: 130 paramedics were given a single clinical scenario. Then they were randomly assigned 12 computerized prehospital ECGs, 6 with and 6 without an accompanying prior ECG. All ECGs were obtained from a local STEMI registry. For each ECG paramedics were asked to determine whether or not there was a STEMI and to rate their confidence in their interpretation. To determine if the old ECGs improved accuracy we used a mixed effects logistic regression model to calculate p-values between the control and intervention.

Results: The addition of a previous ECG improved the accuracy of identifying STEMIs from 75.5% to 80.5% (p=0.015). A previous ECG also increased Paramedic confidence in their interpretation (p=0.011).

Conclusions: The availability of previous ECGs improves paramedic accuracy and enhances their confidence in interpreting STEMIs. Further studies are needed to evaluate this impact in a clinical setting.

Key Words: Emergency Medical Services, Electrocardiography, Myocardial Infarction, Allied Health Personnel

Introduction:

Background:

Coronary Artery Disease (CAD) and Acute Myocardial Infarction (AMI) continue to be a leading cause of morbidity and mortality in the United States. The American Heart Association estimates that each year, an estimated 620,000 Americans suffer from a new coronary attack with another 295,000 with a recurrent attack[1]. While a great many AMI patients travel to the Emergency Department by private vehicle, a large percentage utilize Emergency Medical Services (EMS) for the initial evaluation of chest pain.[2] ECGs are a vital component of the initial evaluation and management of the acute chest pain patient in the emergency department or in the out-of-hospital setting. Early ST segment elevation myocardial infarction (STEMI) identification and notification has led to significant decreases in door-to-balloon times[3] as well as the development of destination protocols that indicate a trend toward improved patient outcomes.[4] Because of this, the American College of Cardiology and its affiliates endorse prehospital ECG use as the standard of care in evaluating and treating potential STEMI patients.[5]

Current literature suggests that paramedics can accurately identify a STEMI on ECG. [6-9] Despite this growing body of literature, there are still concerns among hospital providers over potential false prehospital cardiac catheterization laboratory activations[10]. False activations by paramedics can lead to an increase in medical care costs and general mistrust by emergency physicians and cardiologists. Davis et al demonstrated that while paramedics are proficient at ECG interpretation, transmission of prehospital ECGs to Emergency physicians improves the positive predictive value of the ECG for therapeutic decision-making [6]. This study, combined with the growing body of literature suggests that leaders in out-of-hospital care should further investigate strategies to maximize prehospital provider accuracy in STEMI identification.

Emergency physicians routinely utilize old ECGs when evaluating patients with chest pain. Of the only available evidence, Fesmire found that patients with an ECG that is in fact different from a previous ECG, were six times more likely to have an AMI.[11] The authors concluded that change was a useful predictor for interventions, complications, and AMI in patients with ECGs that were initially positive.[11] Could this clinical tool be utilized in the prehospital arena?

Importance:

EMS systems are rapidly becoming partners in health information exchange[12] . Prehospital patient data is not only being pushed to the hospitals, but many EMS systems are beginning to push patient information out into the field in an effort to improve prehospital patient care. The use of prior ECGs could potentially have a positive impact on paramedic interpretation when managing potential STEMI patients. This information could be included in the data being pushed to the field and serve as a valuable tool that can be easily taught and utilized by prehospital personnel. Improved performance on ECG interpretation could lead to increased acceptance of prehospital cardiac catheterization laboratory activation. Additionally, paramedics providing comparison ECGs to Emergency Physicians could further expedite cardiac care. Furthermore, if shown to be effective, previous ECGs could be an additional tool utilized by medical directors faced with the challenge of improving ECG performance for their services.

Goals of this investigation:

The following study aimed to investigate the impact the availability of prior ECGs has on paramedic interpretation in a simulated clinical scenario. We hypothesized that the availability of prior ECGs among EMS providers would improve paramedic accuracy and improve confidence in recognition of STEMI.

Methods:

Study Design and Setting

We performed a prospective randomized crossover study evaluating the impact of a prior ECG on paramedics' ability to accurately, and confidently, interpret prehospital ECG. Our EMS system, a large urban third service model, utilizes electronic medical record software and recently introduced the capability for paramedics to electronically access prior hospital ECGs from their portable laptop computers during patient care. This study was performed by administering an electronic test with 12 ECGs to paramedics, who were given a standardized patient case scenario.

Selection of Study Participants

Study participants were paramedics employed by a single large urban EMS agency with over 90,000 runs per year, with an average of 6,000 chest pain runs per year. Paramedics participated in the survey as part of their continuing education requirements. All testing was performed on the EMS agency's online learning management system (MC Strategies™) and administered by an EMS educator. A total of 142 paramedics were eligible to participate in this study based on full time employment with the EMS service. Participants were excluded if they failed to complete the test during the designated testing period or failed to complete the required demographic information form. The study was conducted over a 4-month period from February 11th 2013 to June 10th 2013. The Indiana University School of Medicine and the Methodist

Hospital institutional review boards approved the study and all participating paramedics provided informed consent.

ECG Inclusion Criteria*:*

All test ECGs were selected from the Indiana University Health Methodist Hospital STEMI Registry, initially created in 2010 for the purpose of quality improvement. This STEMI registry included all STEMI activations from January 2010 to December 2011, including activations from the prehospital and inpatient setting. The registry included STEMI ECGs and ECGs that did not meet STEMI criteria. All clinical outcomes were recorded (i.e. patient demographics, catheterization laboratory activation, final cardiac catheterization results).

In order to generate our test database we included all ECGs that met the following criteria: 1. Prehospital STEMI activation; 2. ECG was done in the prehospital setting; 3. A prior ECG was available for comparison. There were 205 prehospital STEMI activation ECGs in the registry. Of these, 106 were excluded from our database due to inability to find the prehospital ECGs in the medical record. Of the remaining 99, 49 were excluded due to a lack of prior ECGs for comparison. This left 50 ECGs that comprised the test pool. All computer based interpretation findings and patient identifiers were removed prior to testing.

Prior to administration of the test, two EMS Physicians, blinded to the clinical information, independently reviewed all included ECGs and determined whether the ECG represented a STEMI. Any disagreements were resolved by an independent third EMS physician. The final physician interpretation of the ECG was the gold standard used for determining paramedic accuracy. Of the 50 test ECGs, 24 were determined to be STEMIs and 26 were determined not to be STEMIs. Raw agreement between the two reviewers was 92%.

Methods and Measurements:

All of the paramedics studied were individually given a computer-based test administered by an EMS educator as part of an in-service training. The providers were separated during the test administration so that answers could not be compared. Providers were later excluded from data collection if they did not complete the test or if they failed to complete the demographic information sheet. After completion of the demographic information sheet, the provider was given 30 minutes to complete a 12-question test. The test was comprised of 2 separate question sets. The first was a set of 6 prehospital ECGs alone (diagnostic ECG), and the second set had prehospital ECGs (diagnostic) paired with its corresponding previous ECG for comparison. A single standard patient scenario describing a 56 y/o male presenting with sub sternal chest pain occurring while exercising was applied to all the ECGs and was provided at the beginning of the test. All test ECGs were randomly assigned from the test ECG bank previously described.

Outcomes:

For each question the paramedic was asked to decide whether or not they would activate a "STEMI Alert" (prehospital Cardiac Catheterization lab activation) based on the diagnostic ECG given and were also asked to rate their confidence in their reading as very confident, somewhat confident, or low confidence (Figure 1). The answers regarding their decision to activate a "STEMI Alert" were scored against the gold standard defined above.

Analytical Methods

To compare the intervention, we used a mixed effects logistic regression model to calculate all p-values. For each logistic regression, a fixed effect for the intervention was entered as well as a random effect for paramedic to account for clustering of observations within paramedic. When adjusting for paramedic characteristics, they were entered as fixed effects in the model. Sensitivity, specificity, and Likelihood ratios were calculated for both question sets (ECG only and ECG with comparison). All analyses were performed using SAS v9.2.

RESULTS:

Characteristics of Study Subjects:

A total of 142 paramedics took the examination. 12 providers were excluded for the following reasons: No demographic sheet obtained (6), demographic sheet incomplete (2), refusal to complete demographic sheet (1), unable to complete both exams due to computer technical issues (3). Therefore we had a total of 130 providers enrolled in the study.

The characteristics of the 130 paramedics are presented in Table 1.   Approximately 68% of paramedics had 12 lead training in their initial paramedic science program and 30% reported routine use of 12 leads. All paramedics in the study population received 12-lead training prior to implementation of 12 lead-acquisition by the EMS service.

Main Results:

Paramedic accuracy in identification of STEMI improved significantly from 75.5% to 80.5% (p=0.015) when a prior ECG was available for comparison. In addition, the percentage of answers rated as "Very Confident" increased from 51.8% to 57.8% with the additional ECG (p=0.011). These results are presented in Table 2. Specifically, we found the availability of the additional comparator ECG did not significantly change sensitivity (p=0.13); the sensitivity of a single ECG compared to that with the additional ECG was 84% (95%CI 80 to 88%) versus 80% (95%CI 76% to 84%). However, with the additional ECG, the specificity increased significantly

($p<0.01$) from 67% (95%CI 63% to 72%) to 81% (95%CI 77% to 85%). The resulting LR- without and with the additional ECG was 0.23 (95%CI 0.18 to 0.30) and 0.25 (95%CI 0.20 to 0.30), respectively. Comparatively, the LR+ were 2.59 (95%CI 2.24 to 3.00) without the previous ECG and 4.18 (95%CI 3.42 to 5.16) with the additional ECG.

Other paramedic characteristics such as age, years as paramedic, and 12 lead training in paramedic school did not appear to have an effect on accuracy or confidence (Table 3 and 4).

Limitations:

One limitation of this study is the use of a simulated patient care scenario. The providers were given a standard case, which could affect answers. Further research must be done to explore whether or not our results can be expanded to the practicing clinical environment. Another limitation of our study was the potential of a learned effect. While the test questions were randomized, we did not randomize the order of test questions (they were all given 6 test ECGs, and 6 test ECGs with prior for comparison). Additionally, this study was performed on providers from one system. It is unclear if our results could be extrapolated to other EMS systems. Finally, the accuracy (75-80%) and sensitivity is below that previously reported in the literature[6,8]. A potential reason for this could be attributed to the simulated environment or due to the removal of the computer ECG interpretation. This lower accuracy could lead to exaggerated results.

Discussion:

Our study demonstrated that the availability of prior ECGs improved paramedic performance in 12-lead ECG interpretation. While the absolute measured difference was modest, our results did show significance. With previous studies demonstrating high level of accuracy in paramedic STEMI identification[8], our results suggest that the addition of prior ECGs for comparison could lead to an even higher level of accuracy. This result was demonstrated by the increase in specificity and therefore LR+ with addition of previous ECGs. As the accuracy of paramedic ECG interpretation increases, we hypothesize that there will be greater acceptance of cardiac catheterization lab capable hospitals to incorporate paramedic 12-lead interpretation in their STEMI care pathways.

Paramedic performance in STEMI identification is at the center of the debate on whether paramedics should be activating cardiac catheterization laboratories. In a recent study, Cone et al, demonstrated that door-to-balloon (D2B) times were significantly better for EMS field activations when compared with walk-in patients[13]. Additionally, the compliance with the ACC/AHA recommendation of D2B time less than 90 minutes was 100% in the EMS field group[13]. These results stress the importance of paramedic activation versus activation by the physician at the receiving facility.

In our current state of cost containment and budget cuts one cannot ignore the financial impact of reducing unnecessary emergent catheterizations. The cost of a false positive catheterization including hospital observation and incidental charges is over $17,000 at our institution. We postulate that improving EMS accuracy in reading ECGs with the assistance of a prior ECG could decrease the number of false positive emergent cath lab activations and this could be directly translated into considerable cost savings overall.

While some evidence suggests that prehospital cath lab activation leads to an improvement in quality metrics, this may not translate into improved clinical outcomes. A meta-analysis performed by Brooks and colleagues concluded that there is not enough evidence to recommend the direct transport of STEMI patients to PCI centers over the closest hospital[14]. Despite this evidence, there are a growing number of EMS systems that are utilizing prehospital activations of cardiac catheterization laboratories. This trend, combined with research showing a supportive, yet variable, perception in the value of the paramedic's ECG interpretation[10], demonstrates an increased need to find ways to improve paramedic accuracy. All of these studies suggest a need for continued investigation into ways to improve paramedic ECG interpretation.

This study is the first of its kind to investigate the impact of prior ECGs on paramedic accuracy and confidence in interpreting prehospital ECGs. With the increase in the amount of electronic health information being pushed to our prehospital providers, this is another tool that can be potentially used to improve paramedic STEMI identification. Early studies demonstrated that paramedics were able to adequately identify STEMIs in the field[8,9]. However, recent literature has questioned whether paramedic interpretation of prehospital ECGs has the sensitivity and specificity required to implement prehospital activation of the cardiac catheterization laboratory[15]. Our results demonstrate that the addition of a previous ECG has a substantial impact on the specificity. This can make the role of prehospital 12-lead ECGs in STEMI care ambiguous. Some authors suggest transmission of the prehospital 12 lead [6] or use of a diagnostic scoring systems (i.e. ACI-TIPI)[16] as a way of improving the accuracy and utility of paramedic ECG interpretation. This can be expensive and logistically difficult for many systems forcing EMS leaders to look elsewhere for ways to improve AMI care.

Another implication of our study could have an impact on 12-lead analysis programs. Currently, the majority of prehospital 12-lead analysis programs do not routinely compare current and prior ECGs when analyzing the ECG. Future devices could be designed so that they can receive a prior ECG and perform a serial comparison, therefore improving paramedic utilization of prior ECGs. This, and other potential, incorporation of prior ECGs in prehospital 12-lead devices may assist in overcoming some of the logistical issues EMS systems may face when trying to determine how to incorporate prior 12 lead ECGs into their protocols.

Many EMS medical directors and educators stress that strong education programs and coordinated medical oversight into training programs may improve accuracy. This study provides yet another strategy to improve paramedic performance in this high-risk clinical scenario.

Paramedic educators and many EMS experts have recognized the importance of strong, structured continuing education programs that enhance paramedic performance in various medical areas. Concurrently, the integration of electronic medical records (EMR) with EMS systems is growing[17,18]. Our study is the first of its kind to look at the integration of EMRs to improve paramedic performance in 12-lead ECG interpretation. As the role of health care records expand in EMS, Medical Directors are tasked with deciding what data should be pushed out. If made available, this is a simple tool that can be utilized by paramedics to improve patient care in this time sensitive condition. If set up properly, this additional piece of information can be added with little to no increase in EMS to Balloon or Door to Balloon Time. By improving paramedic accuracy and confidence in ECG interpretation, EMS systems can further improve STEMI care by expediting door-to-balloon times or improving patient delivery to designated PCI centers.

There is literature that demonstrates that paramedics often have trouble identifying the more uncommon STEMI presentations (e.g. lateral) and STEMI mimics[15]. While these STEMI mimics are rare, there is still a need to improve paramedic performance. Additionally, improper activation of cath labs based on STEMI mimics (LBBB or Left Ventricular Hypertrophy) can lead to unnecessary cost to the patient and could potentially be detrimental to the trust that receiving hospitals have on EMS cath lab activation. Additionally, a prior ECG may be helpful in identifying chronic ST elevation, which is another relatively common STEMI mimic encountered by EMS providers. While this study did not specifically address uncommon STEMI or STEMI mimics, there is a potential role for utilization of previous ECGs in improving performance in these two cases. Future studies will need to investigate this further.

The future of EMS care may look beyond identification of STEMI but additionally, early identification of patients with Acute Coronary Syndrome (ACS). The prehospital identification of ACS through comparison ECGs can help to route patients appropriately and aid Emergency Physicians in the first few minutes of care. By recognition of ACS in the field, paramedics can preferentially transport patients to cardiac care centers who are equipped to handle ACS patients. As demonstrated by Fesmire and colleagues[11], changes in ECGs in patients can be an early indicator of ACS, and having prior ECGs for comparison could empower the paramedic to make this judgment. Empowering paramedics to serve as part of the larger emergency care team, by providing key historical and clinical input, can only serve to improve quality and outcomes in an already challenging environment of care.

Although the availability of prior ECGs may not be a reality for all EMS systems currently, this would be a novel tool to add to current Electronic Medical Record capabilities. This study showed that the availability of previous ECGs improves paramedic accuracy and enhances their confidence in interpreting STEMIs. Further research is needed to explore the impact of our findings in a clinical setting as well as to investigate the impact on patient outcomes.

Conclusion:

The availability of previous ECGs improves paramedic accuracy and enhances their confidence in interpreting STEMIs. Further studies are needed to evaluate this impact in a clinical setting.

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Table 1. Paramedic Characteristics (n=130)

	Mean (%)
% Routine use of old 12 leads	39 (30)
% 12 lead training in paramedic school	89 (68.5)
Mean age (SD)	36.3 (9.6)
Mean Paramedic Years (SD)	9.1 (7.5)
Mean Hours/Month	176.3 (70.7)

Table 3. Mixed Effects Logistic Model for association of intervention with correct diagnosis adjusting for other characteristics

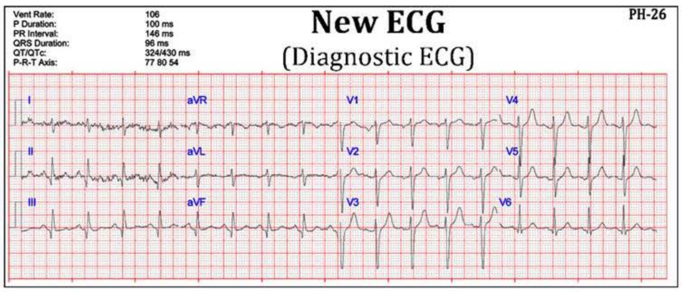
	OR	**95% CI**	**P-value**
Intervention	1.36	(1.06, 1.75)	0.015
Age	0.98	(0.95, 1.01)	0.289
Years Paramedic	1.01	(0.97, 1.06)	0.597
Hours/Month	1.00	(0.99, 1.01)	0.274
Routine use old leads (No vs. Yes)	0.93	(0.65, 1.33)	0.691
12 lead training in paramedic school (No vs. Yes)	0.95	(0.60, 1.49)	0.817

Table 4. Mixed Effects Logistic Model for association of intervention with confidence adjusting for other characteristics

	OR	**95% CI**	**P-value**
Intervention	1.32	(1.07, 1.65)	0.011
Age	0.99	(0.96, 1.03)	0.688
Years Paramedic	0.96	(0.91, 1.02)	0.160
Hours/Month	1.00	(0.99, 1.01)	0.098
Routine use old leads (No vs. Yes)	1.09	(0.72, 1.64)	0.693
12 lead training in paramedic school (No vs. Yes)	1.28	(0.72, 2.16)	0.352

Figure 1. Example Test Question

Text: Based on the ECG below labeled "New ECG", determine if you would call a STEMI alert (i.e. activate cath lab). Pick the answer below that best reflects your decision and your confidence in that decision



Answer Choices:

A. **Activate:** *Very confident* that this is a STEMI
B. **Activate:** *Somewhat confident* that this is a STEMI
C. **Activate:** *Low confidence* That this is a STEMI
D. **No Activation:** *Low confidence* that this ECG does NOT represent a STEMI
E. **No Activation:** *Somewhat confident* that this ECG does NOT represent a STEMI
F. **No Activation:** *Very confident* that this ECG does NOT represent a STEMI