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A Statewide Assessment of Prehospital Electrocardiography Approaches of Acquisition and Interpretation for ST-Elevation Myocardial Infarction Based on Emergency Medical Services Characteristics

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Abstract

Background: The American Heart Association recommends acquiring and interpreting prehospital electrocardiograms (ECG) for patients transported by Emergency Medical Services (EMS) to the emergency department with symptoms highly suspicious of acute coronary syndrome. If interpreted correctly, prehospital ECGs have the potential to improve early detection of ST-elevation myocardial infarction (STEMI) and inform prehospital activation of the cardiac catheterization laboratory, thus reducing total ischemic time and improving patient outcomes. Standardized protocols for prehospital ECG interpretation methods are lacking due to variations in EMS system design, training, and procedures.

Objectives: We aimed to describe approaches for prehospital ECG interpretation in EMS systems across North Carolina (NC), and examine potential differences among systems.

Methods: A 35-item internet survey was sent to all NC EMS systems (n=99). Questions pertaining to prehospital ECG interpretation methods included: paramedic, computerized algorithm (i.e., software interpretation), combined approaches, and/or transmission for physician

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interpretation, transmission capability, cardiac catheterization laboratory activation, and EMS system characteristics (e.g. rural versus urban). Data were summarized and compared.

Results: A total of 96 EMS systems across NC responded to the survey (97% response rate); of these, 69% were rural. EMS medical directors (53%) or EMS administrative directors (42%) completed the majority of surveys. While 91% of EMS systems had a prehospital ECG interpretation protocol in place, only 61% had a written cardiac catheterization laboratory activation policy. More than half (55%) of systems reported paramedic interpretation of prehospital ECGs, followed by a combined paramedic and software interpretation approach (39%), physician interpretation (4%), or software interpretation only approach (2%). Nearly 80% of EMS systems transmitted prehospital ECGs to receiving hospitals (always or sometimes), regardless of interpretation method. All EMS systems had some paid versus non-paid EMS personnel and the majority (86%) had both basic and advanced life support capabilities.

Conclusions: Most NC EMS systems had a paramedic only ECG interpretation or paramedic in combination with a computerized algorithm approach. Very few used a physician read approach following transmission, even in rural service areas.

Keywords

Prehospital; electrocardiography; acute coronary syndrome; ST-elevation myocardial infarction; cardiovascular systems of care

Introduction

The American Heart Association (AHA) recommends that emergency medical services (EMS) acquire and interpret a prehospital electrocardiogram (ECG) for patients with suspected acute coronary syndrome.[1] The ECG is reported to be the single most important method to rapidly identify ST-elevation myocardial infarction (STEMI) in emergency settings and remains the gold standard for detection of acute myocardial infarction/ischemia because it is non-invasive, readily available, and relatively inexpensive.[2] Both rapid and accurate identification of STEMI are important because reperfusion therapy is associated with improved patient outcomes. Electrocardiographic changes, namely ST-segment elevation, may indicate acute myocardial infarction/ischemia and drive clinical decisions about life-saving treatments for STEMI patients.[3]

EMS providers can rapidly acquire prehospital ECGs in the prehospital environment, yet variations in prehospital ECG protocols exist across EMS systems [4] There remains a lack of standardized protocols for prehospital ECG acquisition and interpretation approaches because EMS systems vary by design, training, and procedures. The AHA recommends three basic approaches for interpretation of the prehospital ECG: computer algorithm (i.e, software interpretation), trained paramedic, and/or electronic transmission for physician interpretation.[1,5] There are pros and cons of each, for example software interpretation and paramedic interpretation are considered faster compared to transmission for physician interpretation. Conversely, software interpretation tends to have higher cancellation rates of the cardiac catheterization laboratory compared to paramedic and physician interpretations. [1,6] The objectives of our study were to describe current prehospital ECG protocols and examine differences by EMS characteristics including provider training level, agency characteristics, and geographic settings

Material and methods

The Institutional Review Board at University of North Carolina at Chapel Hill approved our survey-based study. We also obtained a letter of support from the North Carolina Office of Emergency Medical Services (NCOEMS). EMS in North Carolina (NC) is highly organized and well equipped with ECG technology, thus providing a robust opportunity to characterize current prehospital ECG protocols and inform future standardized practice in prehospital cardiac care. Each EMS system in NC is comprised of all the agencies in a county under the direction of a single medical director responsible for oversight of all prehospital care. NC has 100 counties, of which two are combined into one EMS system for a total of 99. Current NC EMS state protocols for STEMI were reviewed in the context of our study (url accessed April 22, 2019).[7] Per NCOEMS protocols for chest pain patients, EMT-Basic, EMT-Intermediate, and paramedics are all authorized to acquire prehospital ECGs; paramedics are authorized to interpret prehospital ECGs.

We developed a 30-item web-based survey (Qualtrics, Appendix A) based on previous work by Jollis et al., which included questions about statewide EMS protocols.[8] We surveyed EMS about their STEMI system of care, defined as an integrated group of separate entities focused on reperfusion therapy for STEMI within a geographic region that includes at least one hospital capable of percutaneous coronary intervention (PCI) and an EMS system.[8] In NC, most PCI-capable hospitals offer PCI around the clock (24 hours/day, 7 days per week), though some do not. We also included questions about EMS characteristics (e.g., pay status, level of training, service area type), protocols for acquiring, interpreting, and transmitting ECGs to hospitals; procedures and protocols for activation of cardiac catheterization labs and hospital characteristics (e.g., PCI-capability). We distributed our Qualtrics survey electronically by email to all EMS system medical directors (n=99) across NC during 2017-2018. We conducted email and telephone follow-up for non-respondents, up to three attempts over the one-year period. EMS administrative directors were contacted if medical directors were not available to complete the survey. Each online survey took approximately 7-10 minutes and data were stored electronically in the Qualtrics secure servers.

We exported data to SAS software for statistical analyses and summarized survey responses with descriptive statistics and computed frequencies and proportions with SAS 9.4 (SAS Institute, Cary, NC). We stratified prehospital ECG approaches by urban/rural areas and paid/volunteer systems.

Results

Ninety-six EMS systems across NC responded to the survey (97% response rate); of these 68 (71%) served rural counties. EMS medical directors (n=51, 53%), EMS administrative directors (n=38, 40%), or other respondents (n=7, 7%) completed the surveys.

EMS Characteristics

Table 1 shows EMS system characteristics in NC. Over half (n=54, 56%) of NC EMS systems had all paid personnel and the remainder had combined paid and volunteer personnel (n=42, 44%). The majority of EMS systems had both basic life support (BLS) and advanced life support (ALS) qualifications (n=85, 89%), followed by ALS certification only (12%). Most EMS systems reported having a written policy or guideline that determined which hospital STEMI patients were transported to (n=92, 96%). Furthermore, 85(89%) of EMS system had a STEMI system of care in place. EMS medical directors were responsible for overseeing the EMS role in most STEMI systems in NC (n=91, 95%).

Prehospital ECG Acquisition and Interpretation

Ninety-three (97%) of EMS systems had prehospital ECG capability in all ambulances and the majority (n=87, 91%) had a standardized protocol in place for prehospital ECG acquisition and interpretation (Table 1). If an initial prehospital ECG was nondiagnostic but a patient remained symptomatic, 67% (n=64) of EMS systems reported acquiring serial prehospital ECGs. Table 2 summarizes prehospital ECG acquisition and interpretation protocols by EMS characteristics. We found that paramedics predominantly acquired prehospital ECGs in NC EMS systems (n=92, 96%). Regarding prehospital ECG interpretation methods, paramedics most commonly interpreted prehospital ECGs in both rural and urban locations (n=53, 55%) and called in the interpretation to the receiving hospital. This was followed by a combination of paramedic and software interpretation approach (n=37, 39%). Nearly 80% of EMS systems (n=76) transmitted prehospital ECGs to receiving hospitals (always or sometimes), regardless of interpretation method, for suspected STEMI findings. However, very few EMS systems (n=4, 6%) reported physician interpretation of ECG after transmission and these were located in rural areas.

A majority of EMS providers (n=62, 65%) were required to receive specific training for prehospital ECG acquisition and interpretation beyond NC state requirements. Over one-third of EMS providers (n=31) reported receiving training once per year and some more than once per year (n=17, 18%). Training was predominantly delivered face to face in a classroom setting (n=60, 63%) followed by an online format (n=37, 39%).

Cardiac Catheterization Activation

In NC, 61% of EMS systems (n=59) had a cardiac catheterization activation policy in place, and of those (48%) reported that paramedics were responsible for activating the cardiac catheterization laboratory (CCL). Of the top 5 hospitals that NC EMS systems transport to, 53 (55%) were reported as PCI-capable. Table 3 illustrates cardiac catheterization activation cancellations by ECG interpretation approaches. More than half (n=54, 56%) of NC EMS systems tracked CCL activation cancellations. Of EMS systems that reported collecting CCL activation cancellation data, systems utilizing the physician interpretation approach (n=2) reported the lowest proportion of cancellations less than 10%.

Discussion

Our findings provide insights to current prehospital ECG practices across an entire state and identify differences by EMS system characteristics. Across NC, paramedics predominantly acquire, transmit, and interpret ECGs regardless of service area type or EMS personnel pay status. Few EMS systems reported ECG transmission to a hospital for physician interpretation, and these were in rural areas. Overall, EMS systems which collected data on CCL activation rates had low cancellation rates, with the majority reporting <10% regardless of interpretation approach utilized.

Paramedics mostly acquired prehospital ECGs followed by intermediate and basic providers in NC. Our findings support prior research that demonstrated EMS acquisition of prehospital ECGs is feasible.[9] Werman et al. (2011) evaluated basic and intermediate (nonparamedic) providers trained to acquire and transmit prehospital ECGs for physician interpretation.[9] They found nonparamedic providers were both capable and reliable for acquisition and transmission of prehospital ECGs; importantly, scene time was not increased with this method.[9] Most EMS systems in NC trained paramedics to interpret prehospital ECGs. Although we were not able to determine the diagnostic accuracy of ECG interpretation approaches, prior research suggests paramedics can accurately interpret ECGs for STEMI with adequate training. Trivedi et al. found paramedics could accurately interpret 12-lead ECGs and activate the CCL.[10] In clinical vignettes that included 12-lead ECG cases, sensitivity and specificity for STEMI diagnosis by paramedics was 92.6% (95% CI 88.9-95.1) and 85.4% (95% CI 79.7-89.8). Neither differences in patient characteristics (e.g., sex) nor paramedics' experience (e.g., years in practice) were associated with diagnostic accuracy.[10] Mencl et al. surveyed paramedics across five systems in Northeastern Ohio about their experience, training, ECG practice, and confidence in STEMI interpretation; the survey also included prehospital ECGs for interpretation.[11] In contrast to Travedi et al., investigators reported low sensitivity 75% and specificity 53% for ECG interpretation. There was low diagnostic accuracy despite more than half the sample reporting ≥10 years of experience as paramedics, recent ECG interpretation training, and routinely acquiring ECGs in the field. [11] Most recently, Huitema et al. examined ECG interpretation by different types of healthcare providers with varying experience.[4] Paramedics made more false positive STEMI diagnoses compared to cardiologists, emergency physicians, fellows, or residents (internal and emergency medicine). Huitema et al., however, determined weekly exposure ≥ 20 tracings was significantly associated with increased accuracy of ECG interpretation across all providers.[4] Although many EMS providers in NC received prehospital ECG training more than once/year, there remain no standards for EMS training, competency assessment, or ongoing quality assurance efforts and therefore illustrates an opportunity for improvement.

EMS providers acquired additional prehospital ECGs when the initial ECG was nondiagnostic if the patient experienced ongoing symptoms and/or had a change in clinical status. These results are important based on the premise that acute myocardial ischemia is dynamic; therefore, a single snapshot ECG may not always capture acute ST-segment changes. The standard ECG has limited sensitivity (30%-70%) and specificity (70%-95%) that results in 2-5% of patients with ACS being erroneously discharged from the ED, and

70% of patients being admitted for suspicious ACS not having it.[12] In a previous study, the sensitivity significantly increased to nearly 80% when both a prehospital ECG and the initial hospital ECG acquired in the ED were considered.[13] Findings underscore the importance of serial ECG monitoring to improve both rapid and accurate diagnosis of acute myocardial ischemia.

Prehospital ECG transmission in NC for physician interpretation was low and limited to rural areas in NC EMS systems. Rural areas pose complex issues and barriers in emergency cardiac care, including transmission problems, the need for training non-paramedic staff to acquire and transmit ECGs, a lack of resources to support programs, and challenges in adopting regionalization protocols.[14] Our low rate of ECG transmission for physician interpretation may reflect the prevalence of paramedics trained to interpret prehospital ECGs across NC EMS systems. The lack of ECG transmission for physician interpretation in urban areas, moreover, may reflect shorter transport times that limit the time available for this approach. In contrast to our findings, Powell et al. found rural areas relied on ECG transmission for physician interpretation in their literature review.[15] They found this approach could extend the benefits of early recognition and intervention to STEMI patients in rural communities, which often depend on volunteer non-paramedic staff. ECG transmission for physician interpretation has been associated with reduction in first medical contact to balloon time and opportunities for medical oversight before patients reach the hospital.[1] Transmission, however, is limited by technology requirements (e.g., dead zones, service provider) and ongoing provider education that focuses on technical aspects and compliance for rapid and reliable prehospital ECG transmission.[16,17]

Lastly, EMS medical directors/administrators reported an overall low cardiac catheterization cancellation rate across NC. Our findings corroborate those by Garvey et al., who conducted a large study of CCL activation rates across 14 PCI-capable hospitals in NC.[18] They reported an overall cancellation rate of 10.6% and determined EMS misinterpretations of prehospital ECG were the main reason for cancellations. Of ECG interpretation approaches, we found physician interpretation via transmission yielded the fewest CCL cancellations. Bosson et al. examined the association between prehospital ECG transmission for physician interpretation and the rate of false cardiac catheterization activations.[19] ECG transmission for physician interpretation reduced false activation rates by 5%, but time to reperfusion was unchanged. Findings from our study support CCL activation for STEMI patients in coordinated EMS systems with physician oversight, training, and continuing education to improve accurate prehospital ECG interpretation, all which are critical to patient outcomes. The low number of systems that utilized this method and reported collecting data on CCL activation cancellations, however, limits this.

Limitations

Our results are limited to EMS medical and administrative directors across NC. This sample may not reflect all EMS systems due to the variability in individual EMS organizations, resources, and geographic area. Data were self-reported and subjective; thus, discrepancies may exist between EMS directors' responses and individual EMS agencies and providers. The subjectivity of survey responses is a limitation to our study.

Although we collected data about approaches of ECG interpretation, we were not able to compare the diagnostic accuracy of the different methods. To inform future prehospital STEMI protocols, it would be beneficial to directly compare diagnostic accuracy by ECG interpretation methods. This is a focus of our ongoing parent study.

Conclusion

Prehospital ECGs have been successfully integrated into STEMI systems of care across NC. Most NC EMS systems have both basic and advanced EMS providers, and all systems had some paid providers. In NC, paramedics are primarily responsible for ECG acquisition and interpretation across both rural and urban settings, and a few rural EMS systems relied on ECG transmission for physician interpretation. These findings can inform ongoing efforts in the regional coordination of EMS systems and hospitals for the rapid diagnosis and treatment of STEMI.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

Prehospital electrocardiogram (ECG) acquisition and interpretation are associated with early diagnosis and treatment of ST-elevation myocardial infarction (STEMI). Methods of interpretation (i.e., paramedic, computer, physician) vary across individual emergency medical services (EMS) systems. In North Carolina, the majority of EMS systems train paramedics to acquire and interpret ECGs. Few rural EMS systems relied on transmission for physician interpretation of the ECG, and no urban areas reported this.

Table 1.

Characteristics of EMS systems in NC (2017-2018)

	Total (N=96)(%)
EMS Personnel Pay Status	
All paid	54(56)
Paid and volunteer	42(44)
Level of training for personnel	
Basic Life Support (BLS)	0(0)
Advanced Life Support (ALS)	11(12)
BLS and ALS	85(89)
Service Area Type	
Rural	68(71)
Urban or Suburban	28(29)
STEMI transport policy	92(96)
For patients with high suspicion of ACS symptoms, do you always bypass the closest hospital for one further with PCI-capability?	30(31)
Number of EMS systems with ECG capability in all ambulances	93(97)
Prehospital ECG standardized protocol in place	87(91)
Who acquires prehospital ECG in ambulance (check all that apply)	
Basic EMT	44(46)
Intermediate	56(58)
Paramedic	92(96)
Physician	2(2)
Nurse	1(1)
If initial prehospital ECG is nondiagnostic but patient is symptomatic, how often do you acquire subsequent ECG(s)?	95(99)
Always	64(67)
Sometimes	31(32)
Never	KD
Number of cardiac catheterization activations per month	
<2	22(23)
2-5	54(56)
6-10	9(9)
>10	10(10)
Unknown	1(1)

EMS – emergency medical services; BLS-basic life support; ALS-advanced life support; STEMI- ST-elevation myocardial infarction; PCI – percutaneous coronary intervention

Table 2.

Protocols for prehospital ECG, STEMI transport, and cardiac catheterization laboratory activation by EMS system characteristics in NC (2017-2018)

	Total (N=96)(%)	Service Area Type		EMS Personnel Pay Status	
		Rural (N=68)(%)	Urban/Suburban (N=28)(%)	All Paid (N=54)(%)	Paid and Volunteer (N=42)(%)
ECG Acquisition					
Basic EMT	44 (45)	30 (44)	14 (50)	24 (44)	20 (48)
Intermediate	56 (58)	40 (59)	16 (57)	27 (50)	29 (69)
Paramedic	92 (96)	64 (94)	28 (100)	53 (98)	39 (93)
Physician	2 (2)	1 (1)	1 (4)	1 (2)	1 (2)
Nurse	1 (1)	1 (1)	0 (0)	1 (1)	0 (0)
ECG Interpretation Approach					
Paramedic only	53 (55)	38 (56)	15 (54)	32 (59)	21 (50)
Software only	2 (2)	2 (3)	0 (0)	1 (2)	1 (2)
Combined paramedic and software	37 (39)	24 (35)	13 (46)	21 (39)	16 (38)
Physician via transmission	4 (4)	4 (6)	0 (0)	0 (0)	4 (10)
ECG Transmission					
Always	30 (31)	21 (31)	9 (32)	19 (35)	11 (26)
Sometimes	46 (48)	31 (46)	15(54)	26 (48)	20 (48)
Never	20 (21)	16 (23)	4 (14)	9 (17)	11 (26)
STEMI Transport Policy	92 (96)	64 (94)	28 (100)	53 (98)	39 (93)
STEMI System of Care Status					
In place	85 (89)	59 (87)	26 (93)	49 (91)	36 (86)
Planned/considered	8 (8)	7 (10)	1 (4)	3 (6)	5 (12)
No plan	3 (3)	2 (3)	1 (4)	2 (4)	1 (2)
Cardiac catheterization laboratory activation policy	59 (61)	39 (57)	20 (71)	33 (61)	26 (62)

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Table 3.

Cardiac catheterization cancellations by ECG interpretation approach in NC (2017-2018)

	Do you track prehospital cardiac catheterization laboratory STEMI activation cancellations?				
	Did not track (N=42)	**Tracked (N=54)**			
		<10% cancelled (N=29)	**10-25% cancelled (N=22)**	**25-50% cancelled (N=3)**	**>50% cancelled (N=0)**
ECG Interpretation Approach					
Paramedic only	24	16 (55)	10 (45)	3 (1)	0
Software algorithm only	2	0	0	0	0
Combined paramedic and software	14	11 (38)	12 (55)	0	0
Physician via transmission	2	2 (18)	0	0	0

Note: The proportions of EMS systems that track cardiac cancellations are reported.