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Prehospital Electrocardiography: A Review of the Literature

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Abstract

Introduction—The American Heart Association and other scientific guidelines recommend emergency medical services acquire prehospital (PH) electrocardiography (ECG) in all patients with symptoms of acute coronary syndrome. The purpose of this article is to critically review the scientific literature about PH ECG.

Methods—Using multiple search terms, we searched the PubMed and Web of Science databases for relevant information. Search limiters were used: human, research (clinical trials, experimental), core journals, and adult. All articles about the clinical effects of PH ECG published between 2001 and 2011 were retained, in addition to a landmark study from 1997.

Results—Our search yielded a total of 105 articles when all years of publication were considered. When the same search was limited to articles published between 2001 and 2011 for new and current data, 45 articles were returned. A total of 7 articles about the clinical effects of PH ECG were retained for this review. Articles were conceptualized and organized by clinical effects of PH ECG (timing, reperfusion rate, death, ejection fraction, reinfarction, and stroke). PH ECG has been associated with reduced PH delay time, increased use of reperfusion interventions, earlier diagnosis, and faster time to treatment.

Discussion—PH ECG plays a major role in emergency cardiac systems of care and can facilitate early intervention by identifying patients with acute coronary syndrome sooner.

Keywords

Acute coronary syndrome; Emergency cardiac care; Prehospital electrocardiography; Cardiac systems of care; Ambulance; Review of literature; Nursing education

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To date, much of the focus of prehospital (PH) electrocardiography (ECG) has been on its role in PH cardiac systems of care for patients with ST-segment elevation myocardial infarction (STEMI).[1] Numerous studies have shown that reporting or transmitting PH ECG to the emergency department is an integral part of cardiac systems of care.[2–5] PH ECG drives the decision to bypass what may be the closest hospital for a farther hospital that

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offers definitive care (percutaneous coronary intervention [PCI]) for patients with STEMI. PH ECG facilitates earlier diagnosis and is an essential component of any rapid intervention strategy.[5] The main benefit of PH ECG lies in its potential to reduce the overall time to administration of reperfusion therapy through several mechanisms.[6,7] The American Heart Association (AHA) gave PH ECG a class I recommendation (supported by strong evidence) in its 2000 Advanced Cardiac Life Support guidelines and is pushing hospital systems to integrate PH ECG into care for patients with acute coronary syndrome (ACS).[1]

Search Strategy

We conducted a review of the literature using the PubMed and Web of Science databases to identify key articles about PH ECG. Search terms used alone and in combination with "AND" and "OR" included the following: prehospital ECG, electrocardiography, emergency medical services, acute coronary syndromes, myocardial ischemia, and myocardial infarction. Search limiters were used: human, research (clinical trials, experimental), core journals, and adult. Our search yielded a total of 105 articles when all years of publication were considered. Because this area of science is quickly developing, the same search was limited to articles published between 2001 and 2011 for new and current data, and 45 articles were returned. Articles about the clinical effects of PH ECG published in the past decade were retained, in addition to a landmark study by Canto et al.[8] from 1997. A total of 7 articles were conceptualized and organized by clinical effects of PH ECG (timing, reperfusion rate, death, ejection fraction, reinfarction, and stroke) and are summarized in the Table.

Studies Establishing PH ECG's Impact on Time, Reperfusion Rate, and Other Clinical Factors

Most of the literature about PH ECG has focused on the clinical effects of PH ECG on time savings and patient outcomes. Both prospective nonrandomized studies and randomized trials have analyzed time intervals, early ventricular function, death, and long-term survival as measures of clinical effect.[9] The primary time intervals that have been reported in the literature include, but are not limited to, symptom onset until first ECG, time to hospital arrival, and time to reperfusion intervention. To date, the principal clinical benefit of PH ECG is the reduction of time from cardiac symptom onset to initiation of reperfusion therapy.[6–8] PH ECG has been associated with increased use of reperfusion interventions, a shortened time to treatment once a patient reaches the hospital, and a greater utilization of cardiac interventions.[8]

Canto et al.[8] conducted the first large study that compared patients with PH ECG (n = 3,768) with patients without PH ECG (n = 66,995) who were enrolled in the National Registry of Myocardial Infarction (NRMI) database (NRMI-2). This was the first study to evaluate the clinical effects of PH ECG. The investigators found that the median times from symptom onset both to first ECG acquisition (120 minutes vs 108 minutes) and to hospital arrival (152 minutes vs 91 minutes) were significantly longer ($P < .001$) in the PH ECG group than in the no–PH ECG group. Despite longer times, however, the hospital time to reperfusion therapy was significantly shorter in the PH ECG group than in the no–PH ECG group (30 minutes vs

40 minutes for thrombolytic therapy ["door to drug"] and 92 minutes vs 115 minutes for PCI ["door to balloon"], $P < .001$). Furthermore, the proportion of patients who received reperfusion therapy was significantly greater in the PH ECG group versus the no–PH ECG group (43% vs 37% for thrombolytic therapy and 11% vs 7% for PCI, $P < .001$). Canto et al. found no significant differences in outcomes of recurrent ischemia or recurrent infarction between the two groups. However, the PH ECG group had less heart failure and hypotension, and the unadjusted hospital mortality rate in the PH ECG group was significantly lower than that in the no–PH ECG group (8% vs 12%, $P < .001$). Lastly, they found that PH ECG was an independent predictor of lower overall mortality rate.

The study by Canto et al.[8] was innovative because they further identified and described specific characteristics about hospitals in communities with PH ECG capability. They found that such facilities tended to have a larger mean number of staffed beds and ED visits per year than those facilities without PH ECG capability. PH ECG community facilities were also more likely to have coronary arteriography, angioplasty, and cardiac surgery capabilities than hospitals not receiving patients with PH ECG. Of note, more than 75% of patients in this study presented to hospitals in communities with PH ECG capabilities, although PH ECG was only obtained in a minority of patients.

Although the study by Canto et al.[8] was a seminal study on the topic of PH ECG, a major limitation was the inability to distinguish between PH ECG obtained by emergency medical services (EMS) versus ECG obtained in a physician's office. The AHA recommends that patients call 911 (and not their physician) if they have symptoms of acute myocardial infarction. If Canto et al. had reported on the time from symptom onset to first ECG in the subgroup who appropriately activated the EMS system, there may have been a shorter median time to first ECG in the PH ECG group compared with the no–PH ECG group. Study findings may be limited because they are based on hospitals in the NRMI database. There is potential for nonconsecutive patient enrollment and lack of independent onsite validation of data forms; moreover, registry hospitals may not be representative of all US hospitals.

Brainard et al.[6] conducted a systematic review of research literature that reported time savings of PH 12-lead ECG. This meta-analysis of studies conducted in the United States (1966–2004) was necessary because the AHA's class I recommendation for PH ECG was based entirely on studies conducted in Europe. Thus it was unclear whether the European study findings could be applied to the American emergency cardiac care system. For example, much of the European data were collected in EMS systems that had ambulances staffed with physicians or paramedics who administered fibrinolytics in the field, characteristics not typical of the United States. One of the major strengths of this meta-analysis was its inclusion of studies that had strong study designs (including treatment and control groups) and appropriate outcome measures. There were several factors that enhanced the internal validity of the meta-analysis. Studies in which patients received PH ECG acquired by EMS were included, unlike in the study by Canto et al.,[8] which also included ECG obtained in a physician's office. Extraneous variance was controlled for because all studies included patients admitted to the emergency department, not directly to the cardiac catheterization laboratory or coronary care unit. Time savings findings for this meta-analysis were concluded from 4 different articles (N = 99) and were consistent with the study findings of Canto et al. There was a mean reduction of 22 minutes (95% confidence interval [CI], 20.04–24.0) in time to hospital reperfusion intervention between those who received PH ECG and those who did not. The mean time to reperfusion was 36.5 minutes (95% CI, 32.4–40.6) for the PH ECG group versus 58.5 minutes (95% CI, 56.1–60.9) for the no–PH ECG group.

It is unclear whether reperfusion intervention included fibrinolytic therapy, PCI, or both, which may be a threat to construct validity.[6] Other inherent limitations of this meta-analysis are its dependency on previously published research and the accompanying bias of each. Lastly, the studies that were included spanned nearly a 40-year time period, and it is likely that time-to-treatment improvements may have been due to many factors in addition to whether PH ECG was performed.

Curtis et al.[7] conducted a large observational study of data from the NRMI-4 database to determine the effects of PH ECG on door-to-reperfusion times. This more recent study can be directly compared with the study by Canto et al.[8] in its design and purpose. The study included 56,647 patients with acute myocardial infarction enrolled in NRMI-4 between January 2000 and December 2002. Inclusion criteria were restricted to patients with STEMI or left bundle branch block identified on their first ECG study who received reperfusion therapy (within 6 hours of admission). The primary outcome of interest was time from hospital arrival to either (1) administration of fibrinolytic therapy (door to drug) or (2) time to first PCI balloon inflation (door to balloon). The acquisition of PH ECG was associated with significantly shorter door–to–reperfusion intervention times. The mean door-todrug time was 24.6 minutes for patients with PH ECG and 34.5 minutes for those without PH ECG ($P < .001$). The mean door-to-balloon time was 83.9 minutes for patients with PH ECG and 107.7 minutes for those without PH ECG ($P < .001$). These findings are in accordance with the previous studies that have been evaluated and may show the stability of PH ECG benefits over time. An important difference from the study by Canto et al. is the interval between symptom onset and hospital arrival time. There was no increase in time in this study,[7] in contrast to the longer symptom–to–hospital arrival interval that Canto et al. reported in 1997. In fact, the mean time was shorter for both the fibrinolytic and PCI cohorts receiving PH ECG (83 minutes vs 95 minutes, $P < .01$; 80 minutes vs 103 minutes, $P < .01$).[7] This shorter time may be explained by paramedics responding more quickly to patients who they perceived as having acute myocardial infarction. Unlike previous studies reported, Curtis et al. added the important consideration of guideline recommendations in their findings. In the fibrinolytic cohort, 60.6% (95% CI, 58.1–63.0) of patients with PH ECG received therapy within the guideline-recommended 30 minutes of hospital arrival as compared with 40.8% (95% CI, 40.3–41.3) of those without PH ECG ($P < .001$). In the PCI cohort, 55.2% (95% CI, 52.9–57.6) of patients with PH ECG received reperfusion therapy within 90 minutes compared with 33.1% (95% CI, 32.5–33.8) of those without PH ECG ($P < .001$).

Eckstein et al.[10] conducted a more recent retrospective study that compared door-to-balloon times for STEMI patients transported by paramedics who received PH ECG with patients who arrived by self-transport. This is an important comparison because most patients with

ACS present to emergency departments by self-transport.[11] Four urban hospitals with PCI capability were included in the study. A total of 234 patients were evaluated between January and December 2005. Inclusion criteria were explicitly stated and were an admission diagnosis of STEMI and a hospital discharge diagnosis of acute myocardial infarction. The time variables evaluated were (1) time to catheterization laboratory and (2) time to balloon inflation. Medical records were reviewed for data collection.

In agreement with the previous studies discussed, clinical time intervals were less for patients who received PH ECG.[10] The median times from ED arrival to arrival to the catheterization laboratory were 64 minutes for the EMS transport group versus 77 minutes for the self-transport group (95% CI of time savings, 18.5–27.2; $P < .05$). Median door-to-balloon times were 95 minutes for the EMS transport group versus 108 minutes in the self-transport group (95% CI of time savings, 3.5–16.4; $P < .05$). The time savings of 13 minutes in door-to-balloon time was less than the 22 minutes reported in the meta-analysis by Brainard et al.[6] EMS transport was associated with shorter door-to-balloon times, and although this did not achieve statistical significance, this may be a clinically significant finding. Some of the limitations of this study were inherent, given its retrospective design, because data were abstracted from medical records, which may be a threat to the internal validity of the study because of inaccurate or missing documentation. This study was conducted in an urban setting that was establishing STEMI receiving centers, so its findings may not be generalizable to suburban/rural hospitals.

Diercks et al.[12] recently conducted a very large study to determine the association of PH ECG and the timing of reperfusion therapy for STEMI patients. They also wanted to determine nationwide use and impact of PH ECG. Subjects were enrolled in the National Cardiovascular Data Registry (NCDR ACTION) between January and December 2007. A large cohort of 12,097 patients was enrolled who presented with STEMI by EMS or self-transport and met the following inclusion criteria: (1) persistent ST-segment elevation or new left bundle branch block, (2) presentation within 24 hours of ischemic symptom onset, (3) initial evaluation in emergency department, and (4) non-transfer patients. Among 7,098 patients transported by EMS, only 1,941 (24.7%) underwent PH ECG. Patients with PH ECG were more likely to undergo primary PCI and less likely to receive no reperfusion therapy compared with those who did not receive PH ECG. In addition, those with PH ECG achieved faster door-to-drug times (19 minutes vs 29 minutes, $P < .003$) and door-to-balloon times (61 minutes vs 75 minutes, $P < .0001$) than those without PH ECG. Diercks et al. found that patients with PH ECG were more likely to meet time-to-treatment guideline recommendations for both fibrinolytic therapy (49.1% vs 72.4%, $P = .05$) and PCI (70.0% vs 82.3%, $P < .0001$), confirming findings from the study conducted by Curtis et al.[7] in 2006.

Most recently, Drew et al.[13] conducted a large randomized clinical trial that compared patients with and without PH ECG in terms of paramedic scene time (time spent in the field with no wheels rolling) and time to treatment (door to balloon in STEMI patients and door to first intravenous ACS drug in non-STEMI and unstable angina pectoris patients). A total of 794 patients were enrolled from June 2003 to June 2008. Inclusion criteria included all patients transported by ambulance for symptoms suggestive of ACS, aged 30 years or older, who were not in cardiac arrest at EMS arrival, had a successful PH ECG transmission, and consented to participate in the study. A total of 74% of the patients who called 911 with ACS symptoms over the 5-year study period received PH ECG. This is higher than the 24.7% previously reported by Diercks et al.[12] in 2009; however, the latter study was different because only patients with STEMI were included. The mean scene time in patients with PH ECG was 2 minutes longer than that in those without PH ECG (18 ± 6 minutes vs 16 ± 6 minutes, $P < .05$). The mean door-to-balloon time in STEMI patients with PH ECG was 78 ± 22 minutes compared with 101 ± 56 minutes in those without PH ECG ($P = .197$). The mean door–to–first intravenous drug time was 23 ± 12 minutes in those with PH ECG versus 31 ± 16 minutes in those without PH ECG ($P < .05$).

This study was the first to prospectively evaluate time to reperfusion and outcomes in patients randomized to PH ECG versus no PH ECG.[13] Although the faster time-to-intervention findings are in agreement with previously discussed studies about STEMI,[6–8,12] this study further examined times for non-STEMI and unstable angina. It was also the first study to use a 5-electrode lead configuration with continuous ST-segment monitoring in the field from which synthesized PH ECG was obtained. This simple strategy was associated with significantly greater paramedic PH ECG acquisition.[13]

Effects of PH ECG on Death, Ejection Fraction, Reinfarction, and Stroke

Ioannidis et al.[9] conducted a meta-analysis to determine characteristics of the clinical effects of PH ECG. A total of 10 studies, both prospective and retrospective, were reviewed. Inclusion criteria were explicit and included patients in the PH setting with chest pain who received ECG. In a review of 2 nonrandomized studies, left ventricular ejection fraction (at discharge or within 1 week after admission) was better in the PH ECG group and reached statistical significance. Conversely, short-term effects on ejection fraction from 5 randomized trials showed no significant difference between the PH ECG and control groups. Finally, the in-hospital mortality rate was 8% in the PH ECG group versus 12% in the control group ($P < .001$). Cumulative findings in these 4 randomized trials suggested an overall survival benefit in PH ECG groups. The impact on longer-term mortality rate (1- and 2-year follow-up) was inconclusive, because only 4 trials attempted to evaluate long-term mortality rate and all 4 had missing data. This is a problem inherent in longitudinal study designs. Although statistical findings were reported for some of the characteristics discussed earlier, the study was weakened by a lack of statistical reporting for several important characteristics that were evaluated. This makes it difficult to draw conclusions about PH ECG from the meta-analysis.[9]

Summary

Research findings consistently show that PH ECG is associated with significantly shorter door-to-reperfusion times for both fibrinolytic therapy and PCI. Furthermore, a higher proportion of patients with PH ECG receive reperfusion therapy within guideline-recommended timeframes. There are discrepancies in scene time or symptom onset–to–hospital arrival time in the literature, and these may be because of variability in data reporting. It is difficult for patients to reliably recall when their symptoms began. Other studies may have obtained these data from EMS reports. More importantly, longer scene times do not appear to affect a faster time to reperfusion therapy in patients who receive PH ECG. Lastly, the in-hospital survival benefit of PH ECG is inconclusive, and to date, no studies have evaluated the implications on long-term survival for those who receive PH ECG.

Emergency Nursing Implications

Emergency cardiac care systems require the coordination of multiple EMS agencies and hospitals in a region. An important leadership role for emergency nurses is to facilitate how PH ECG will be used and integrated into these systems of care. Emergency nurses should become knowledgeable not only in 12-lead ECG interpretation but also in integrating the diagnostic information that PH ECG offers to optimize care for patients with ACS. Future work by nurse researchers interested in emergency cardiac care should investigate long-term survival benefits of those with PH ECG and whether PH ECG provides more useful diagnostic information beyond an initial hospital ECG recording obtained on arrival to the emergency department.

Conclusion

Numerous studies have shown that reporting or transmitting PH ECG to the emergency department is an integral part of treatment for patients with ACS. The main benefit of PH ECG lies in its potential to reduce the overall time to administration of reperfusion therapy. In addition, it enhances early arrival and triage to the emergency department and is associated with increased use of reperfusion interventions, shortened time to treatment, and greater use of cardiac interventions.

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TABLE

Summary of articles about PH ECG

Author (date of publication)	Purpose	Inclusion criteria	Outcome variables	Level of evidence
Canto et al[8] (1997)	To compare characteristics and outcomes of patients with or without PH ECG	Hospitalized patients with AMI who presented by ambulance to emergency department	Time to first ECG, time to reperfusion therapy, clinical outcomes (reinfarction, heart failure, hypotension, death)	IIb
Ioannidis et al[9] (2001)	To assess diagnostic performance of PH ECG	Studies about patients with chest pain who received PH ECG; both RCT and non-RCT studies included for meta-analysis	Sensitivity, specificity, clinical outcomes (death)	Ia
Brainard et al[6] (2005)	To compare time to reperfusion in patients with or without PH ECG	Studies that reported time savings of PH ECG; all needed to report original data	Onset of symptoms—to—reperfusion time	Ia
Curtis et al[7] (2006)	To evaluate prevalence of PH ECG and effects of PH ECG on reperfusion times	Patients with STEMI or new left bundle branch block who received acute reperfusion therapy	Door-to-drug time and door-to-balloon time	IIb
Eckstein et al[10] (2009)	To compare time to reperfusion in patients with or without PH ECG	Patients with admission diagnosis of STEMI	Door-to-balloon time	IIb
Diercks et al[12] (2009)	To compare time to reperfusion and clinical outcomes in patients with or without PH ECG	Patients with admission diagnosis of STEMI	Door-to-balloon time, clinical outcomes (death, heart failure, cardiogenic shock)	IIb
Drew et al[13] (2011)	To compare time to reperfusion and clinical outcomes (scene time) in patients with or without PH ECG	Patients activating EMS with chest pain and/or anginal equivalent	Scene time, time to first ECG, time to reperfusion, clinical outcomes (death)	Ib

AMI, Acute myocardial I'nfarction; *RCT,* randomized control trial.