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Journal of Electrocardiology 48 (2015) 520 – 526

JOURNAL OF Electrocardiology

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# Normal prehospital electrocardiography is linked to long-term survival in patients presenting to the emergency department with symptoms of acute coronary syndrome☆

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**Abstract**

**Aims/methods:** We studied 735 patients who activated "911" for chest pain and/or anginal equivalent symptoms and received 12-lead ECG monitoring with specialized ischemia monitoring software in the ambulance. Prehospital electrocardiograms (PH ECG) were analyzed to determine the proportion of patients who present with completely normal PH ECG findings (absence of ischemia/infarction, arrhythmia, or any other abnormality) and to compare outcomes among patients with and without any PH ECG abnormality.

**Results:** Of 735 patients (mean age 70.5, 52.4% male), 68 (9.3%) patients had completely normal PH ECG findings. They experienced significantly less adverse hospital outcomes (12% vs 37%), length of stay (1.19 vs 3.86 days), and long-term mortality (9% vs 28%) than those with any PH ECG abnormality ($p < .05$).

**Conclusion:** Normal PH ECG findings are associated with better short and long-term outcomes in ambulance patients with ischemic symptoms. These findings may enhance early triage and risk stratification in emergency cardiac care.



*Keywords:* Acute coronary syndrome; Emergency medical services; Prehospital electrocardiography; ST-segment monitoring

## Introduction

Acute coronary syndrome (ACS) is a life-threatening complication of coronary heart disease (CHD) and remains a top cause of death in the United States [1]. Each year, nearly 6 million patients present to the emergency department (ED) with chest pain and 620,000 are diagnosed with acute myocardial infarction (AMI) [2,3]. An estimated 10–59% of patients with chest pain activate the emergency medical system (EMS) for transport to the hospital. Prehospital triage and identification of patients with ACS are critical since each minute of delay from symptom onset to intervention for AMI increases mortality [4,5]. Conducting a prehospital electrocardiogram (PH ECG) is becoming the standard of care for patients activating EMS and the American Heart Association (AHA) designated PH ECG a class I recommendation (supported by strong evidence) in its 2010 Cardiac Life Support guidelines [6]. Abnormal PH ECG signs of ischemia (ST elevation, ST depression, T-wave inversion) drive early treatment decisions for patients with myocardial infarction such as the decision to bypass what may be the closest hospital for a further one that offers definitive cardiac treatment [7]. Moreover, PH ECG signs of ischemia are independent predictors of adverse hospital outcomes, a final diagnosis of ACS, and direct admission to acute coronary care units [8–10]. PH ECG can also uncover significant arrhythmias that may be indicative of underlying cardiac disease [11].

However, the value of completely normal ECG results (absent of ischemia, arrhythmia, or other abnormalities) in the prehospital setting for patients with chest pain and/or anginal equivalent symptoms is unknown. Therefore, the primary aims of this study were 1) to determine the proportion of patients transported for ischemic complaints with completely normal PH ECG findings, and 2) to describe the incidence of adverse

☆ Funding sources/disclosures: Grant support received from the National Institute of Nursing Research (R01 NR007881).

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http://dx.doi.org/10.1016/j.jelectrocard.2015.01.014
0022-0736/

hospital outcomes, length of hospital stay, and long-term mortality in this population.

## Material and methods

### *Study design*

Data for this retrospective analysis were obtained from the ST SMART (Synthesized Twelve-lead ST Monitoring and Real-time Tele-electrocardiography) Trial, a prospective randomized clinical trial in Santa Cruz County, CA from 2003 to 2009 [12]. The primary aims of the ST SMART Trial were to compare patients with and without PH ECG ST-segment monitoring in paramedic scene time, hospital time to treatment, and survival over the period of the study. The primary outcome measure for the present analysis was to compare two groups (those with completely normal PH ECG and those without normal PH ECG) on the differences in the proportion of adverse hospital outcomes and long-term mortality, and the difference in mean length of hospital stay.

The Institutional Review Boards at the University of California, San Francisco, and the two hospitals in the County approved the study with a waiver of consent in the field to avoid delays in patients reaching the hospital. Community assent was obtained by a front-page report in the county's newspaper (*Santa Cruz Sentinel, 2003*) and by information posted on hospitals' and EMS agencies' websites [12]. Once study participants were comfortable and hemodynamically stable at the hospital, research nurses obtained written consent.

### *Study setting and population*

Enrollment for the study occurred 7 days a week, 24 hours a day in the prehospital setting. All paramedics in Santa Cruz County were trained to include the following: any persons 30 years of age and older who activated "911" with complaints of non-traumatic chest pain and/or anginal equivalent symptoms (i.e. new onset shortness of breath not due to asthma or syncope not due to drug overdose or intoxication). Exclusion criteria were participants who were unwilling or unable to consent [12].

### *Study protocol*

All 26 paramedic-staffed emergency vehicles responding to 911 calls in the county were equipped with specially designed portable monitor-defibrillator devices (Lifepak12, Physio-Control, Redmond, WA) [12]. The study device software was designed to enable: 1) synthesis of a 12-lead ECG from five electrodes, 2) measurement of ST amplitudes (J + 60 milliseconds) every 30 seconds in all 12 leads, and 3) automatic storage and transmission of an ECG to the destination ED if there was a change in ST amplitude of 0.2 mV in 1 lead or 0.1 mV in $\geq 2$ contiguous leads lasting 2.5 minutes [12]. The study device used a bandwidth of 0.05–150 Hz, which is the filtering recommended for diagnostic standard 12-lead ECGs.

A previous validation study was conducted to compare the synthesized 5-lead ECG and standard 12-lead ECG for major diagnoses of interest in the prehospital setting (i.e. myocardial ischemia/infarction, bundle branch block, arrhythmia) [13]. A high percentage of agreement was determined between the synthesized 5-lead PH ECG and standard 12-lead ECG for diagnoses of ACS, thus corroborating use of the 5-lead method for prehospital use in this study [13].

The portable monitor-defibrillator study device collected 20 seconds of electrocardiographic data and then selected the 10 seconds with the best signal-to-noise ratio to develop a noise-free median beat from which all 12-lead ST-segment measurements were obtained. If the initial 20-second sample was noisy, the device automatically analyzed the subsequent 20 seconds of data [12]. The ST SMART monitoring device had ischemia monitoring software designed for exercise stress testing that had powerful noise reduction technology to ensure high quality ECGs.

All county paramedics (n = 83) were taught to apply the 5 electrodes and manually transmit an initial PH ECG for patients with ACS symptoms [12]. The initial manual ECG transmission activated the ongoing ST-segment monitoring software. Any subsequent ST-event PH ECGs were automatically transmitted without paramedic decision-making. To optimize PH ECG transmissions, the device automatically attempted to redial up to 3 times if the EMS vehicle was in a location where mobile telephone communication was unavailable.

PH ECG data were stored in the device and analyzed offline (CodeStat Suite version 8.0, Physio-Control, Redmond, WA). The investigator (JZH) manually analyzed all PH ECGs. Normal PH ECG was defined by the absence of all of the following: ST-T wave changes, arrhythmias, bundle branch block, first degree block, second degree block, third degree block, paced rhythm, left ventricular hypertrophy (LVH), long QT interval, or abnormal axis deviation. All ECG abnormalities are presented in detail in Table 1. The universal criteria for the diagnosis of ACS as defined by the European Society of Cardiology and American College of Cardiology Committee were applied to determine changes of ischemia/infarction [14]. The revised criteria were developed to improve the sensitivity and specificity of the ECG by recognizing gender, age, and lead differences. These include: 1) ST segment elevation at the J-point with cut-off points $\geq 0.2$ mV in men $\geq 40$ years; $\geq 0.25$ mV in men $<40$ years; and $\geq 0.15$ mV in women in leads $V_2$ and $V_3$ or $\geq 0.1$ mV in other leads; 2) horizontal or down-sloping ST segment depression $\geq 0.05$ mV; or 3) T-wave inversion of $\geq 0.1$ mV in leads with prominent R waves or R/S ratio $>1$ [14]. All ECG criteria for ischemia/infarction were required be present in two contiguous leads. An expert (CES) conducted random audits of ECG analysis to establish inter-rater reliability.

Three research nurses were trained for data abstraction exclusively for the ST SMART Trial. They reviewed medical record notes, ICD-9 codes, and conducted follow-up telephone calls to obtain information about the occurrence of adverse hospital outcomes and long-term mortality. Follow-up data were collected at 30 day, 1, 2, 3, and 4-year time periods after hospital discharge. The Social Security Death Index (SSDI) was used for follow-up when research nurses were unable to acquire information by the prior strategies described. A project director conducted random study chart audits to ensure reliable