OPEN ACCESS

ORIGINAL ARTICLE

Effects of prehospital 12-lead ECG on processes of care and mortality in acute coronary syndrome: a linked cohort study from the Myocardial Ischaemia National Audit Project

Tom Quinn,[1] Sigurd Johnsen,[1,2] Chris P Gale,[3,4] Helen Snooks,[5] Scott McLean,[6] Malcolm Woollard,[1] Clive Weston,[5] On behalf of the Myocardial Ischaemia National Audit Project (MINAP) Steering Group

▶ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/heartjnl-2013-304599).

[1]Faculty of Health and Medical Sciences, University of Surrey, Guildford, UK
[2]Surrey Clinical Research Centre, University of Surrey, Guildford, UK
[3]Division of Epidemiology and Biostatistics, University of Leeds, Leeds, UK
[4]Department of Cardiology, York Teaching Hospital NHS Foundation Trust, York, UK
[5]College of Medicine, Swansea University, Swansea, UK
[6]NHS Fife, Kirkcaldy, Fife, UK

Correspondence to
Professor Tom Quinn, Faculty of Health and Medical Sciences, University of Surrey, Guildford, GU2 7XH, UK; t.quinn@surrey.ac.uk

Received 12 July 2013
Revised 10 February 2014
Accepted 6 March 2014

ABSTRACT

Objective To describe patterns of prehospital ECG (PHECG) use and determine its association with processes and outcomes of care in patients with ST-elevation myocardial infarction (STEMI) and non-STEMI.

Methods Population-based linked cohort study of a national myocardial infarction registry.

Results 288 990 patients were admitted to hospitals via emergency medical services (EMS) between 1 January 2005 and 31 December 2009. PHECG use increased overall (51% vs 64%, adjusted OR (aOR) 2.17, 95% CI 2.12 to 2.22), and in STEMI (64% vs 79%, aOR 2.34, 95% CI 2.25 to 2.44). Patients who received PHECG were younger (71 years vs 74 years, $P<0.0001$); and less likely to be female (33.1% vs 40.3%, OR 0.87, 95% CI 0.86 to 0.89), or to have comorbidities than those who did not. For STEMI, reperfusion was more frequent in those having PHECG (83.5% vs 74.4%, p<0.0001). PHECG was associated with more primary percutaneous coronary intervention patients achieving call-to-balloon time <90 min (27.9% vs 21.4%, aOR 1.38, 95% CI 1.24 to 1.54) and more patients who received fibrinolytic therapy achieving door-to-needle time <30 min (90.6% vs 83.7%, aOR 2.13, 95% CI 1.91 to 2.38). Patients with PHECG exhibited significantly lower 30-day mortality rates than those who did not (7.4% vs 8.2%, aOR 0.94, 95% CI 0.91 to 0.96).

Conclusions Findings from this national MI registry demonstrate a survival advantage in STEMI and non-STEMI patients when PHECG was used.

INTRODUCTION

International guidelines recommend that for patients who present with symptoms suggestive of an acute coronary syndrome (ACS), attending emergency medical service (EMS) personnel record a 12-lead ECG before transit to hospital.[1–4] This prehospital ECG (PHECG) may allow targeted treatments to be given outside of a hospital, determine which type of hospital receives the patient, and facilitate activation of the cardiac catheter laboratory.

Failure to perform a PHECG is associated with delayed and denied reperfusion treatment in patients with ST-elevation myocardial infarction (STEMI).[5–9] Although some reports suggest that women are less likely than men to have a PHECG recorded,[10] there is incomplete understanding of the factors associated with the use of PHECG and its impact on processes of care and mortality.

Furthermore, despite calls for widespread implementation, there is little empirical evidence that PHECG is associated with lower mortality.[3 4] That is, much of the previous literature focuses on processes of care such as the time to reperfusion with fibrinolytic drugs, or primary percutaneous coronary intervention (PPCI).[5–9]

In England and Wales, EMS involvement in the care of patients with STEMI is the highest in Europe,[11] and ECGs have been available through the National Health Service (NHS) EMS since 2001. This, along with the availability of national data from the Myocardial Ischaemia National Audit Project (MINAP) concerning patients hospitalised with ACS, provides a unique opportunity to study the use of PHECG in patients with STEMI and non-STEMI and its association with processes of care and mortality.[12]

The a priori hypotheses for this study were that STEMI and non-STEMI patients who did not receive PHECG differed in baseline clinical characteristics from those who did, and that the use of PHECG by EMS systems was associated with better processes of care and lower mortality rates.

METHODS

This study was based on national ACS data from MINAP, participation in which is mandated for all hospitals in England and Wales.[12] Data were collected prospectively at each hospital by a secure electronic system, developed by the Central Cardiac Audit Database (CCAD), electronically encrypted and transferred online to a central database. MINAP is overseen by a multiprofessional steering group representing the stakeholders within the National Institute for Cardiovascular Outcomes Research (NICOR).[13] As such, this study includes data collected on behalf of the British Cardiovascular Society under the auspices of NICOR in which patient identity was protected.

The study population was drawn from 424 866 consecutive patients admitted to hospital with ACS from 228 hospitals. Patients were eligible for study if they were hospitalised between 1 January 2005

To cite: Quinn T, Johnsen S, Gale CP, *et al*. *Heart* Published Online First: [*please include* Day Month Year] doi:10.1136/heartjnl-2013-304599

and 31 December 2009, and aged at least 18 years. For patients with multiple admissions, we used the earliest record.

We studied patients by initial diagnosis of STEMI and non-STEMI, determined by EMS personnel or the hospital clinician responsible for providing definitive treatment. Eligibility for emergency reperfusion therapy was based upon standard practice with a recommendation that patients should have a symptom duration of 12 h or less and ST segment elevation of 0.1 mV or greater in at least two contiguous leads, or 0.2 mV or greater in in V1-V3, or presumed new onset left bundle branch block.

PHECG use was defined as the recording of an ECG by EMS personnel. The date and time of call for help was registered by the EMS and the data transferred into the MINAP database by hospital staff. The date and time of reperfusion (defined as the time of first balloon inflation for PPCI and time of injection for fibrinolytics) were recorded in MINAP by hospital staff.

Each MINAP entry provides details of the patient's management across 122 fields,[14] and date of all-cause mortality from linkage to the Medical Research Information System, part of the NHS Information Centre using a unique NHS number. Data entry is subject to routine online error checking. There is a mandatory annual data validation exercise for each hospital.

Statistical analyses

We used the procedure MEANS of SAS (Statistical Analysis System; SAS, Cary, North Carolina, USA) to obtain percentages, medians and interquartile ranges. ORs, with 95% CIs are presented, being more informative than p values, because the p values resulting from logistic regression with such a large dataset were, without exception, highly significant. SAS (SAS Institute) PROC LOGISTIC was used to obtain the estimates, with the dichotomous dependent variable, for example, PHECG-recorded versus PHECG-unrecorded regressed on the explanatory variables together with standardisation for case-mix using variables including those compatible with the mini-GRACE (Global Registry of Acute Coronary Events) risk score.[15] The covariates chosen are listed under the relevant tables. We used multiple imputation to mitigate bias due to missing data (details in online supplement).

To investigate the extent to which the provision (or not) of reperfusion in STEMI could be predicted by PHECG use, logistic regression was performed. The dependent variable was reperfusion therapy, the independent variables being PHECG, congestive heart failure (CHF), whether or not older than 75 years, previous MI, previous coronary artery bypass grafting (CABG), sex, diabetes mellitus, patient delay in hours, and calendar year of STEMI.[16] Missing values were accommodated as outlined above.

Mortality within 30 days (yes/no) was the dependent variable in a logistic regression (using SAS PROC LOGISTIC) with independent variables: whether or not on aspirin, age in years at admission, Body Mass Index, whether elevated marker set (yes/no), whether chronic renal failure (CRF) (yes/no), whether diabetic (yes/no), whether prior stroke (yes/no), and whether prior CHF (yes/no). An output of this logistic regression exercise, based on the model parameter estimates and the values for each patient of the independent variables for that patient, was a predicted probability of 30-day mortality for that patient. Patients were sorted in descending order by these predicted probabilities, and the resultant dataset divided into terciles (3 equinumerous, non-overlapping, exhaustive subsets). The intermediate versus lowest 30-day mortality risk was the ratio for each subclassification (eg, PHECG, no PHECG), of the corresponding numbers of patients in the middle tercile and in the lowest tercile. For

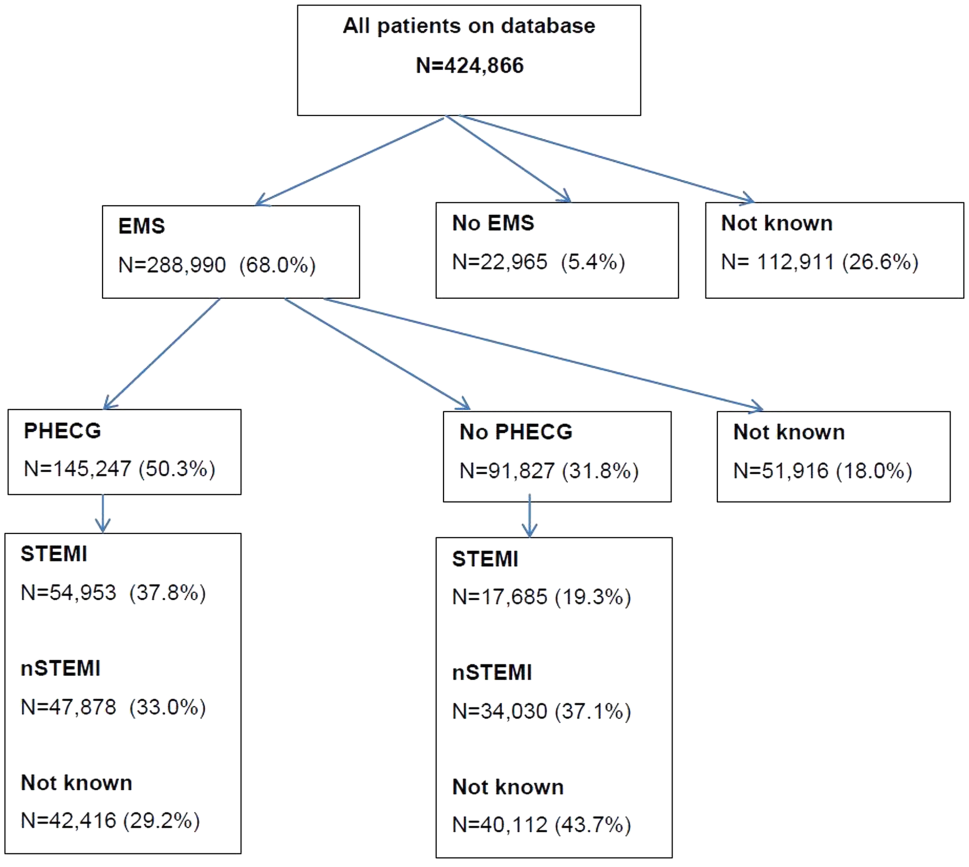

Figure 1 Study flow chart based on initial diagnosis.

the highest versus lowest 30-day mortality risk, the corresponding terciles were the highest and the lowest.

RESULTS

Among 424 866 patients in the MINAP registry for the years of the study, 288 990(68%) were recorded as using EMS, 22 965 (5.4%) were documented as not using EMS, and the method of hospital arrival was unknown for 112 911 (26.6%) (figure 1). Table 1 compares baseline characteristics of patients by EMS use. After adjustment, patients who used EMS were older, more likely to be female, Caucasian, and to have had prior MI, angina, CHF, or chronic pulmonary disease (COPD) than those who did not use EMS.

Of those known to have used EMS, 145 247 (50.3%) received PHECG. Between 2005 and 2009, PHECG use increased overall (51% vs 64%, adjusted OR (aOR) 2.17, 95% CI 2.12 to 2.22) and in STEMI (64% vs 79%, aOR 2.34, 95% CI 2.25 to 2.44). Compared with patients who did not receive a PHECG, those who did were younger (71 years vs 74 years, p<0.0001), less frequently female (33.1% vs 40.3%, OR 0.87, 95% CI 0.86 to 0.89) and had fewer comorbidities. Patients who did not receive PHECG were more frequently hypertensive, had a history of stroke, CHF, CRF, angina, diabetes or (COPD) (table 2). Use of PHECG increased (including among women, older people, patients with CHF and those with comorbidities) over the study period (table 4). Patients who received PHECG had a lower baseline mortality risk measured by mini-GRACE than those who did not.[15]

The recording of PHECG was associated with longer prehospital EMS time intervals. Considering all ACS, the median time from EMS call to arrival at hospital was 6 min longer in patients who had PHECG (52 min (IQR 40.0, 66.0) versus 46 min (IQR 35.0, 62.0). Similarly, time from EMS arrival at scene to hospital arrival was 5 min longer (40 (IQR 31.0, 53.0) vs 35 (26.0, 46.0) min). The same pattern was seen for STEMI (EMS call to hospital arrival 52 (40.0, 666.0) vs 45 (33.0, 62.0) min; time in EMS care 41 (IQR 31.0, 54.0) vs 34 (25.0, 46.0) min).

The use of any reperfusion strategy (PCI or fibrinolytic) in STEMI patients was more frequent in those who had PHECG (85.3% vs 74.4%, P<0.001), after adjustment for confounding factors. Performance of PHECG was predictive of reperfusion therapy in STEMI compared with other patient characteristics (aOR 1.70, 95% CI 1.63 to 1.78) (figure 2).

Door-to-balloon time for patients who received PPCI for STEMI was not influenced by PHECG use (median (IQR): 46.0 (30.0, 71.0) vs 45.0 (28.0, 75.0) min, respectively). However, a significant increase in the proportion of patients who received PPCI within 90 min of calling the EMS was observed when a PHECG was recorded (27.9% vs 21.4%, aOR 1.38, 95% CI 1.24 to 1.54).

For STEMI patients receiving fibrinolytics in hospital, PHECG use was associated with a higher proportion of patients who received treatment within 30 min of arrival (90.6% vs 83.7%; aOR 2.13, 95% CI 1.91 to 2.38). The median door-to-needle interval was 3 min shorter (17 (IQR 12.0, 23.0) versus 20 (14.0, 27.0) min). However, the overall call-to-needle interval was similar between the two groups (59 (IQR 49.0, 72.0) versus 58 (47.0, 73.0 min).

Of 11 172 STEMI patients who received prehospital fibrinolytic therapy, PHECG was recorded by EMS personnel in 10 816, (96.8%). In the remainder, PHECG was performed by non-EMS personnel (eg, primary care physicians) prior to EMS arrival.

Table 1 Baseline characteristics: EMS versus no EMS transportation to hospital

	Overall (n=311 955)	EMS (n=288 990)	No EMS (n=22 965)	OR estimate	95% CI
Basic demographics					
Age (years) *	72 (60, 81)	72 (61, 81)	66 (55, 77)		
Female	35.7%	36.1%	30.7%	1.07	1.04 to 1.09
Caucasian	94.7%	95.0%	92.6%	1.44	1.36 to 1.52
Asian	4.4%	4.2%	6.1%	0.72	0.68 to 0.76
Other race	0.8%	0.8%	1.3%	0.63	0.56 to 0.72
Risk factors					
Hypertension	49.9%	49.9%	50.3%	1.00	0.97 to 1.03
Diabetes Mellitus	19.8%	19.8%	19.5%	1.10	1.06 to 1.14
PAD	4.9%	4.9%	4.8%	0.97	0.91 to 1.03
Current smoker	27.3%	27.2%	29.2%	1.09	1.06 to 1.14
Dyslipidemia	34.5%	34.2%	37.4%	0.96	0.93 to 1.00
Prior history					
Prior MI	28.5%	28.9%	23.0%	1.33	1.27 to 1.38
Prior PCI	9.8%	9.7%	11.5%	0.99	0.95 to 1.03
Prior CABG	6.7%	6.7%	6.8%	1.06	1.00 to 1.13
Prior CHF	6.8%	7.0%	4.7%	1.35	1.27 to 1.44
Prior stroke	9.2%	9.3%	7.2%	1.30	1.22 to 1.39
CRF	5.1%	5.0%	5.7%	0.84	0.80 to 0.89
Prior angina	34.2%	34.8%	26.6%	1.32	1.26 to 1.38
COPD	15.8%	16.0%	13.5%	1.24	1.19 to 1.29

Data expressed as percentages unless indicated.
*Age in median (IQR) years.
CABG, coronary artery bypass graft; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; CRF, chronic renal failure; EMS, emergency medical services; MI, myocardial infarction; PAD, peripheral arterial disease; PCI, percutaneous coronary intervention.

Table 2 Baseline characteristics by PHECG use in patients who came via EMS

	Overall (n=237 074)	PHECG (n=145 247)	No PHECG (n=91 827)	OR estimate	95% CI
Age*	72.0 (60.6, 81.2)	70.7 (59.6, 80.1)	73.9 (62.3, 82.6)		
Female	35.9%	33.1%	40.3%	0.87	0.86 to 0.89
White	95.1%	95.1%	95.1%	1.18	1.15 to 1.22
Asian	4.2%	4.2%	4.1%	0.88	0.85 to 0.91
Other race	0.8%	0.7%	0.9%	0.72	0.65 to 0.80
Hypertension	49.9%	48.8%	51.6%	0.95	0.94 to 0.97
Diabetes mellitus	19.7%	18.6%	21.4%	0.91	0.90 to 0.93
PAD	4.8%	4.4%	5.4%	0.87	0.83 to 0.90
Current smoker	27.3%	29.1%	24.3%	1.21	1.19 to 1.24
Dyslipidemia	34.2%	33.9%	34.6%	0.95	0.93 to 0.96
Prior MI	28.5%	28.2%	29.0%	1.06	1.04 to 1.08
Prior PCI	9.8%	10.2%	9.2%	1.04	1.02 to 1.07
Prior CABG	6.6%	6.6%	6.6%	0.98	0.96 to 1.01
Prior CHF	6.8%	5.7%	8.5%	0.79	0.77 to 0.81
Prior stroke	9.3%	8.4%	10.7%	0.88	0.86 to 0.91
CRF	5.1%	4.4%	6.2%	0.75	0.72 to 0.77
Prior angina	34.3%	33.2%	36.1%	0.97	0.95 to 0.98
COPD	15.9%	14.5%	18.0%	0.87	0.86 to 0.89
SBP (mm Hg, median, IQR)	137.0 (118.0, 156.0)	137.0 (118.0, 156.0)	137.0 (118.0, 157.0)		
Heart rate (beats/min, median, IQR)	78.0 (65.0, 94.0)	77.0 (64.0, 91.0)	80.0 (67.0, 97.0)		
Intermediate vs lowest 30 day mortality risk (mini-GRACE)	50.0%	48.3%	52.9%	1.11	1.06 to 1.17
Highest vs lowest 30 day mortality risk (mini-GRACE)	50.0%	46.9%	55.0%	0.94	0.89 to 0.99

*Age in median (IQR) years.
CABG, coronary artery bypass graft; CHF, chronic heart failure; CRF, chronic renal failure; GRACE, Global Registry of Acute Coronary Events; PAD, peripheral arterial disease; PCI, percutaneous coronary intervention; PHECG, prehospital ECG; SBP, systolic blood pressure.

As PHECG was associated with an increased likelihood of a STEMI patient receiving any reperfusion therapy (figure 2), we sought to determine whether patients who did not have PHECG shared similar characteristics to those who subsequently failed to receive reperfusion treatment for STEMI. The separate baseline characteristics for these two categories were summarised and were clearly different (data on file). On account of the large numbers of patients in each category, and the overlap of patients in the two categories, any statistical judgement on the significances of these differences would be uninformative: the only meaningful comparisons would be ones based on clinical judgement.

Patients who received a PHECG exhibited significantly lower hospital and 30-day mortality rates than those who did not (30-day mortality 7.4% vs 8.2%, aOR 0.94, 95% CI 0.91 to 0.96). Most of the differences were attributable to significantly

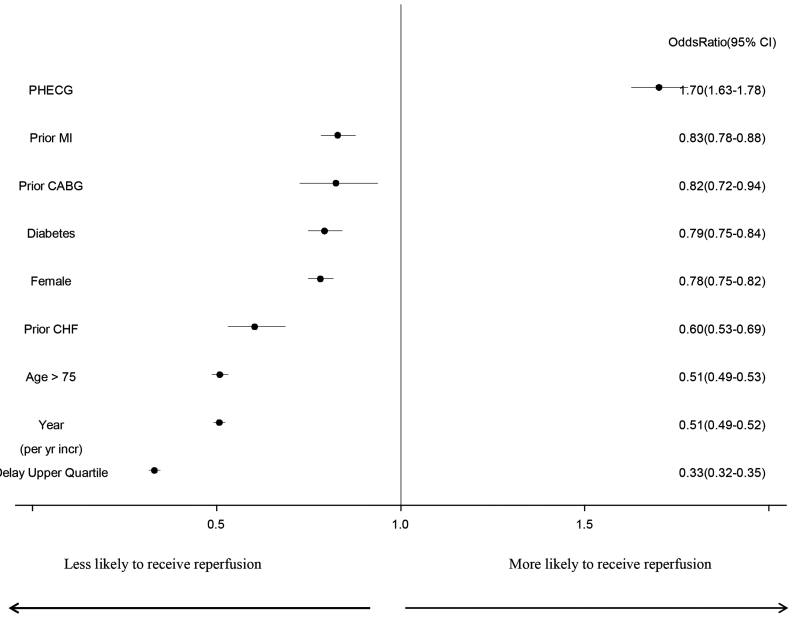

Figure 2 Characteristics associated with use of reperfusion therapy in patients with acute ST-elevation myocardial infarction (STEMI): influence of prehospital 12-lead ECG.

Table 3 Hospital and 30-day mortality by PHECG use

Mortality	Overall	PHECG	No PHECG	Adjusted OR	95% CI
Total population	(n=154 546)	(n=102 831)	(n=51 715)		
Hospital	4.2%	4.0%	4.7%	0.85	0.82 to 0.88
30 day	7.6%	7.4%	8.2%	0.94	0.91 to 0.96
STEMI patients	(n=72 638)	(n=54 953)	(n=17 685)		
Hospital	5.2%	4.8%	6.6%	0.88	0.84 to 0.93
30 day	9.3%	8.6%	11.4%	0.94	0.90 to 0.98
STEMI patients receiving reperfusion therapy*	(n=62 412)	(n=48 533)	(n=13 879)		
Hospital	4.3%	4.0%	5.4%	0.92	0.85 to 0.99
30 day	7.8%	7.3%	9.4%	0.94	0.89 to 1.00
STEMI patients receiving fibrinolytic agents	(n=42 604)	(n=33 394)	(n=9210)		
Hospital	5.0%	4.6%	6.4%	0.91	0.84 to 1.00
30 day	8.9%	8.3%	10.9%	0.95	0.88 to 1.01
STEMI patients receiving pPCI	(n=14 063)	(n=11 015)	(n=3048)		
Hospital	3.1%	2.9%	3.6%	0.89	0.72 to 1.12
30 day	5.2%	5.0%	6.0%	0.91	0.77 to 1.07
STEMI patients not receiving any reperfusion therapy	(n=10 226)	(n=6420)	(n=3806)		
Hospital	10.6%	10.5%	11.0%	0.86	0.80 to 0.93
30 day	18.7%	18.6%	18.8%	0.96	0.90 to 1.03
nSTEMI patients	(n=81 908)	(n=47 878)	(n=34 030)		
Hospital	3.3%	3.1%	3.7%	0.76	0.72 to 0.80
30 day	6.1%	5.9%	6.5%	0.84	0.81 to 0.88

EMS, emergency medical services; PHECG, prehospital ECG; pPCi, primary percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.

lower rates of mortality in STEMI patients who received a PHECG (8.6% vs 11.4%, aOR 0.94, CI 0.90 to 0.98). There was no difference in mortality by PHECG in STEMI patients who did not undergo any reperfusion strategy (18.6% vs 18.8%, aOR 0.96 95% CI 0.90 to 1.03). Patients with non-STEMI who received a PHECG had lower mortality than those who did not (5.9% vs 6.5%, aOR 0.84, 95% CI 0.81 to 0.88). (table 3).

DISCUSSION

This study demonstrates that, in patients presenting with symptoms of ACS, PHECG use is significantly associated with a reduction in mortality during the 30 days following hospitalisation. This mortality benefit was seen in STEMI (where there was an association between PHECG and an increased likelihood of, and reduced delay to, reperfusion) and in non-STEMI. PHECG use increased over the study period (including among women, older people, CHF patients and those with comorbidities), but was still suboptimal at approximately two-thirds of eligible patients with ACS (almost 80% in STEMI). Patients with higher mortality risk at baseline, as assessed using the mini-GRACE score, were less likely to receive PHECG.

Although prehospital time was increased for those who had received PHECG, in-hospital processes of care were improved, particularly for STEMI. Moreover, the risk of death was lower in STEMI and non-STEMI even after adjustment for confounding effects. In-hospital and 30-day mortality rates in those receiving PHECG and PPCI for STEMI were 11% and 4% lower, respectively—suggesting a similar beneficial effect as in most other groups of patients, but in this case failing to reach statistical significance at the 95% level.

Our study population differs from previously published series in several ways. First, our patients were older; 72 (60, 81) years compared with 61 years in the NRMI-4 Registry,[5] and 62 (52,75) years in the NCD-ACTION Registry,[8] and 62 years in the series reported by Patel *et al*.[17] The proportion of EMS patients who were female was similar to NCD-ACTION[8] (36.1% vs 34.1%) but lower than the 47% reported by Patel *et al*.[17]

Previous reports suggest sex differences in prehospital management of ACS. Rothcock *et al* reported that PHECG use was significantly lower in women than men (32.9% vs 39.3%, $p<0.001$).[18] Our study suggests that patients who did not have PHECG were more frequently older, female and comorbid.

Table 4 Changes in use of PHECG in patients who used EMS, by year

PHECG use—no./total no. (%)					
Year	Overall	Female	>75 years	CHF	Comorbidities
2005	16 465/32 410 (51)	5515/11 874 (46)	6259/13 464 (46)	953/2332 (41)	12 425/25 053 (50)
2006	26 545/44 568 (60)	8848/16 031 (55)	10 233/18 581 (55)	1465/2874 (51)	19 915/34 048 (58)
2007	30 303/47 806 (63)	9915/16 968 (58)	11 826/20 264 (58)	1669/3003 (56)	22 740/36 627 (62)
2008	33 431/51 812 (65)	10 935/18 411 (59)	12 787/21 554 (59)	1831/3388 (54)	25 317/39 976 (63)
2009	38 503/60 478 (64)	12 690/21 545 (59)	15 084/25 265 (60)	1970/3653 (54)	28 907/46 402 (62)

CHF, chronic heart failure; EMS, emergency medical services; PHECG, prehospital ECG.

It is possible that, in a predominantly male EMS workforce, staff were reluctant to undertake PHECG in female patients because of the need for intimate exposure. This phenomenon has been reported elsewhere.[18 19] Meisel *et al*[20] found that including EMS provider sex in their logistic regression model did not change differences observed between patient sex and rates of prehospital use of ACS protocol interventions (although PHECG was not included in the EMS protocols). We did not collect data on patient preferences, and it is possible that women were less likely than men to consent to having a PHECG recorded.

We have shown that, in contrast to other patient variables, having a PHECG recorded is associated with the provision of reperfusion therapy for STEMI. In an analysis of the GRACE,[16] PHECG was not included in the model to assess characteristics associated with failure to use reperfusion therapy.

The role of the PHECG in patients with non-STEMI ACS has received little attention in previous studies. Cudnick *et al*[10] reported that of 21 151 patients with non-STEMI in the NCDR-ACTION-get with the guidelines (GWTG) registry, a PHECG was documented in only 1609 (7.6%), and the primary outcomes of interest were process measures including use of aspirin, β-blocker and heparin and length of stay in the Emergency Department (ED). Since MINAP does not collect these data, we were unable to compare our findings. Cudnick *et al* did not find an association between PHECG and lower mortality for non-STEMI. The precise mechanism whereby the recording of a PHECG was associated with lower mortality in our series remains unexplained and requires further evaluation.

Our study should be interpreted in the context of the following limitations. Given the observational nature of our research, we are not able to establish causality.[21] Our analysis was dependent upon the extent and validity of data in the MINAP database. We used multiple imputation to mitigate bias due to missing data.[22] It is possible, however, that those with missing data were the most seriously ill, and it was more difficult to obtain and record accurate data for the MINAP database (eg, those who died prior to hospital arrival or in the ED), and we cannot exclude this potential source of bias.

MINAP does not collect data on presenting symptoms, and we were therefore unable to ascertain clinical indications for recording a PHECG. Nor were we able to distinguish between cases where the PHECG was transmitted electronically for expert review (eg, by a cardiologist[23] or cardiac care unit (CCU) nurse[24]) or interpreted by EMS staff. Ducas *et al*[25] report that non-physician EMS interpretation of PHECG is safe and reliable. We were also unable to ascertain the skill level of EMS staff: in England and Wales, ambulances are staffed by a combination of paramedics (trained in advanced life support and ECG interpretation) and emergency medical technicians trained in basic life support and use of an automated external defibrillator, but not in ECG interpretation. It is possible that paramedics underwent a different process of clinical assessment and decision making, and this may have implications for appropriateness of cardiac catheter laboratory activation.[26] It is possible that increased availability of PPCI following publication of national guidance in 2008 could result in an increase in PHECG use, but we did not identify an increase in PHECG use from 2008 to 2009 (table 4).[27]

CONCLUSIONS

Findings from this national MI registry demonstrate for the first time a survival advantage in STEMI and non-STEMI patients when PHECG was used. This study strengthens the evidence base for guidelines which recommend PHECG. However, use was variable, indicating the need for quality improvement interventions. Such interventions need to be evaluated through randomised trials in order to provide rigorous evidence of their clinical and cost effectiveness.

Key messages

What is already known on this subject?

- Use of the PHECG has been recommended in international guidelines for ST-elevation myocardial infarction (STEMI), but while several reports of the impact of processes, such as reperfusion times have been published, there have been no data exploring the association of PHECG with patient outcome, and little is known about the impact of PHECG on patients with non-STEMI ACS.

What this study adds

- Findings from this national MI registry demonstrate for the first time a survival advantage associated with PHECG use, in patients with STEMI and non-STEMI. It also identifies categories of patients in whom PHECG is underutilised.

How might this impact on clinical practice?

- This study strengthens the evidence base for existing guidelines, and identifies the need for interventions to increase PHECG use in categories of patients in which it is currently underutilised.

Acknowledgements We thank Lucia Gavalova, MINAP Project Manager, NICOR, and Carol Stilwell and Patrick McCabe from Surrey Clinical Research Centre for support with data release, data management and statistical advice. EMS and hospital personnel for data collection. MINAP is supported by the British Cardiovascular Society under the auspices of the National Institute for Cardiovascular Outcomes Research (NICOR); commissioned and funded by the Healthcare Quality Improvement Partnership.

Contributors Author contributions: TQ had full access to all data in the study and takes responsibility for the integrity of the data and accuracy of the data analysis. Study concept and design: TQ, SJ, HS, CW. Acquisition of data: TQ, CW. Analysis and interpretation of data: TQ, SJ, CPG, HS, CW. Drafting of the manuscript: TQ, SJ. Critical revision of the manuscript for important intellectual content: TQ, SJ, CPG, HS, SM, MW, CW. Statistical analysis: SJ. Obtained funding: TQ, SJ. Administrative, technical or material support: TQ, SJ, CPG, CW. Study supervision: TQ, CW.

In memoriam This paper is submitted in memory of William Quinn.

Funding British Heart Foundation project grant PG/11/54/28 996.

Competing interests Quinn has received funding from Boehringer Ingelheim, the Medicines Company and the National Institute for Health Research in relation to prehospital trials of acute coronary syndrome care. No other authors have interests to declare.

Ethics approval National Research Ethics Service South East Coast—Brighton and Hove (REC 11-LO-0317) Permission for release of the dataset for analysis was given by the MINAP Academic Group; and University of Surrey Ethics Committee

Disclaimer The content is solely the responsibility of the authors and does not necessarily represent the official views of the British Heart Foundation, NICOR or the Healthcare Quality Improvement Partnership. This study used a linked database. The interpretation and reporting of these data are the sole responsibility of the authors.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 O'Gara PT, Kushner FG, Ascheim DD, *et al*. 2013 ACCF/AHA Guideline for the Management of ST-Elevation Myocardial Infarction: a Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol* 2013;61:485–510.
2 Steg PG, James SK, Atar D, *et al*. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Task Force on the management of ST-segment elevation acute myocardial infarction of the European Society of Cardiology (ESC). *Eur Heart J.* 2012;33:2569–619.
3 Garvey JL, MacLeod BA, Sopko G, *et al*. National Heart Attack Alert Program (NHAAP) Coordinating Committee; National Heart, Lung, and Blood Institute (NHLBI); National Institutes of Health. Pre-hospital 12-lead electrocardiography programs: a call for implementation by emergency medical services systems providing advanced life support—National Heart Attack Alert Program (NHAAP) Coordinating Committee; National Heart, Lung, and Blood Institute (NHLBI); National Institutes of Health. *J Am Coll Cardiol* 2006;47:485–91.
4 Ting HH, Krumholz HM, Bradley EH, *et al*. Implementation and integration of pre-hospital ECGs into systems of care for acute coronary syndrome: a scientific statement from the American Heart Association Interdisciplinary Council on Quality of Care and Outcomes Research, Emergency Cardiovascular Care Committee, Council on Cardiovascular Nursing, and Council on Clinical Cardiology. *Circulation* 2008;118:1066–79.
5 Curtis J, Portnay E, Wang Y, *et al*. The Pre-Hospital Electrocardiogram and Time to Reperfusion in Patients With Acute Myocardial Infarction, 2000–2002. Findings From the National Registry of Myocardial Infarction-4 J. *Am Coll Cardiol* 2006;47:1544–52.
6 Brainard AH, Raynovich W, Tandberg D, *et al*. The pre-hospital 12-lead electrocardiogram's effect on time to initiation of reperfusion therapy: a systematic review and meta-analysis of existing literature. *Am J Emerg Med.* 2005;23:351–6.
7 Morrison LJ, Brooks S, Sawadsky B, *et al*. Pre-hospital 12-lead electrocardiography impact on acute myocardial infarction treatment times and mortality: a systematic review. *Acad Emerg Med*. 2006;13:84–9.
8 Diercks DB, Kontos MC, Chen AY, *et al*. Utilization and impact of pre-hospital electrocardiograms for patients with S-T segment elevation myocardial infarction. Data from the NCDR (National Cardiovascular Data Registry) ACTION (Acute Coronary Treatment and Intervention Outcomes Network) Registry. *J Am Coll Cardiol* 2009;53:161–6.
9 Zègre Hemsey JK, Drew BJ. Prehospital electrocardiography: a review of the literature. *J Emerg Nurs*. 2012;38:9–14.
10 Cudnick MT, Peacock FW, Diercks DB, *et al*. Pre-hospital electrocardiograms (ECGs) do not improve the process of emergency department care in hospitals with higher usage of ECGs in non-ST- segment elevation myocardial infarction patients. *Clin Cardiol* 2009;32:668–74.
11 Widimsky P, Wijns W, Fajadet J, *et al*. Reperfusion therapy for ST elevation acute myocardial infarction in Europe: description of the current situation in 30 countries. *Eur Heart J* 2010;31:943–57.
12 Herrett E, Smeeth L, Walker L, *et al*. MINAP Academic Group. The Myocardial Ischaemia National Audit Project (MINAP). *Heart* 2010;96:1264–7.
13 Gale CP, Weston C, Denaxas S, *et al*. NICOR Executive. Engaging with the clinical data transparency initiative: a view from the National Institute for Cardiovascular Outcomes Research (NICOR). *Heart.* 2012;98:1040–3.
14 Weston CF, Birkhead JS, Van Leeven R, *et al*. How the NHS cares for patients with heart attack. MINAP Tenth public report. Myocardial Ischaemia National Audit Project. 2011. National Institute for Cardiovascular Outcomes Research, University College London. http://www.ucl.ac.uk/nicor/audits/minap
15 Simms AD, Reynolds S, Pieper K, *et al*. Evaluation of the NICE mini-GRACE risk scores for acute myocardial infarction using the Myocardial Ischaemia National Audit Project (MINAP) 2003–2009: National Institute for Cardiovascular Outcomes Research (NICOR). *Heart* 2013;99:35–40.
16 Eagle KA, Nallamothu BK, Mehta RH, *et al*. Global Registry of Acute Coronary Events (GRACE) Investigators. Trends in acute reperfusion therapy for ST-segment elevation myocardial infarction from 1999 to 2006: we are getting better but we have got a long way to go. *Eur Heart J* 2008;29:609–17.
17 Patel M, Dunford JV, Aguilar S, *et al*. Pre-hospital electrocardiography by emergency medical personnel: effects on scene and transport times for chest pain and ST-segment elevation myocardial infarction patients. *J Am Coll Cardiol* 2012;60:806–11.
18 Rothrock SG, Brandt P, Godfrey B, *et al*. Is there gender bias in the pre-hospital management of patients with acute chest pain?. *Prehosp Emerg Care* 2001;5:331–4.
19 Daudelin DH, Sayah AJ, Kwong M, *et al*. Improving use of prehospital 12-lead ECG for early identification and treatment of acute coronary syndrome and ST-elevation myocardial infarction. *Circ Cardiovasc Qual Outcomes* 2010;3:316–23.
20 Meisel ZF, Armstrong K, Mechem CC, *et al*. Influence of sex on the out-of-hospital management of chest pain. *Acad Emerg Med* 2010;17:80–7.
21 Heart Group Editors. Statement on matching language to the type of evidence used in describing outcomes data. *Heart* 2012;98:doi:10.1136/heartjnl-2012-303287.
22 Cattle BA, Baxter PD, Greenwood DC, *et al*. Multiple imputation for completion of a national clinical audit dataset. *Stat Med* 2011;30:2736–53.
23 Brunetti ND, De Gennaro L, Dellegrottaglie G, *et al*. A regional prehospital electrocardiogram network with a single telecardiology "hub" for public emergency medical service: technical requirements, logistics, manpower, and preliminary results. *Telemed J E Health* 2011;17:727–33.
24 McLean S, Egan G, Connor P, *et al*. Collaborative decision-making between paramedics and CCU nurses based on 12-lead ECG telemetry expedites the delivery of thrombolysis in ST elevation myocardial infarction. *Emerg Med J* 2008;25:370–4.
25 Ducas RA, Wassef AW, Jassal DS, *et al*. To transmit or not to transmit: how good are emergency medical personnel in detecting STEMI in patients with chest pain? *Can J Cardiol* 2012;28:432–7.
26 Rokos IC, French WJ, Mattu A, *et al*. Appropriate cardiac cath lab activation: optimizing electrocardiogram interpretation and clinical decision-making for acute ST-elevation myocardial infarction. *Am Heart J.* 2010;160:995–1003.
27 Department of Health and British Cardiovascular Intervention Society. Treatment of Heart Attack National Guidance Final Report of the National Infarct Angioplasty Project (NIAP). London, 2008. http://www.bcis.org.uk/resources/documents/NIAP%20Final%20Report.pdf (accessed 23 Oct 2013).

Heart

Effects of prehospital 12-lead ECG on processes of care and mortality in acute coronary syndrome: a linked cohort study from the Myocardial Ischaemia National Audit Project

Tom Quinn, Sigurd Johnsen, Chris P Gale, Helen Snooks, Scott McLean, Malcolm Woollard, Clive Weston and On behalf of the Myocardial Ischaemia National Audit Project (MINAP) Steering Group

Heart published online April 14, 2014

Notes