Performance of hospitals according to the ESC ACCA quality indicators and 30-day mortality for acute myocardial infarction: national cohort study using the United Kingdom Myocardial Ischaemia National Audit Project (MINAP) register

Owen Bebb1,2, Marlous Hall1, Keith A. A. Fox3, Tatendashe B. Dondo1, Adam Timmis4, Hector Bueno5,6,7, François Schiele8, and Chris P. Gale1,2*

1Leeds Institute of Cardiovascular and Metabolic Medicine, University of Leeds, Leeds, UK; 2York Teaching Hospital NHS Foundation Trust, York, UK; 3Centre for Cardiovascular Science, University of Edinburgh, UK; 4NIHR Cardiovascular Biomedical Research Unit, Barts Heart Centre, London; 5Centro Nacional de Investigaciones Cardiovasculares (CNIC), Spain; 6Instituto de Investigacion and Cardiology Department, Hospital Universitario, Spain; 7Universidad Complutense de Madrid, Spain; and 8Department of Cardiology, University Hospital Jean Minjoz, Besancon, France

Received 1 July 2016; revised 7 November 2016; editorial decision 3 January 2017; accepted 9 January 2017; online publish-ahead-of-print 20 February 2017

Aims

To investigate the application of the European Society of Cardiology Acute Cardiovascular Care Association quality indicators (QI) for acute myocardial infarction for the study of hospital performance and 30-day mortality.

Methods and results

National cohort study (n = 118,075 patients, n = 211 hospitals, MINAP registry), 2012-13. Overall, 16 of the 20 QIs could be calculated. Eleven QIs had a significant inverse association with GRACE risk adjusted 30-day mortality (all P < 0.005). The association with the greatest magnitude was high attainment of the composite opportunity-based QI (80-100%) vs. zero attainment (odds ratio 0.04, 95% confidence interval 0.04-0.05, P < 0.001), increasing attainment from low (0.42, 0.37-0.49, P < 0.001) to intermediate (0.15, 0.13-0.16, P < 0.001) was significantly associated with a reduced risk of 30-day mortality. A 1% increase in attainment of this QI was associated with a 3% reduction in 30-day mortality (0.97, 0.97-0.97, P < 0.001). The QI with the widest hospital variation was fondaparinux received among NSTEMI (interquartile range 84.7%) and least variation ‘centre organisation’ (0.0%), with seven QIs depicting minimal variation (<1%). GRACE risk score adjusted 30-day mortality varied by hospital (median 6.7%, interquartile range 5.4-7.9%).

Conclusions

Eleven QIs were significantly inversely associated with 30-day mortality. Increasing patient attainment of the composite quality indicator was the most powerful predictor; a 1% increase in attainment represented a 3% decrease in 30-day standardised mortality. The ESC QIs for acute myocardial infarction are applicable in a large health system and have the potential to improve care and reduce unwarranted variation in death from acute myocardial infarction.

Keywords

Quality indicators • Acute myocardial infarction • Mortality • Hospital performance
### Introduction

Between and within European country variation in the delivery and outcomes from acute myocardial infarction [AMI] suggest that the potential to reduce the burden of cardiovascular disease has not been realized.1–3 Measuring recognized standards of care is a mechanism by which geographic variation in the use of guideline-indicated treatments may be addressed and, therefore, cardiovascular outcomes improved. The 2016 European Society of Cardiology [ESC] Acute Cardiovascular Care Association [ACCA] quality indicators [QI] for the management of AMI4 are based upon the ESC guidelines for the management of AMI in patients presenting with ST-segment elevation5 and acute coronary syndrome in patients presenting without persistent ST-segment elevation.6 They comprise 7 domains across 20 QIs, including the evaluation of: (1) centre organisation, (2) the reperfusion/invasive strategy, (3) in hospital risk assessment, (4) antithrombotic treatment during hospitalization, (5) secondary prevention discharge treatments, (6) patient satisfaction, and (7) composite QIs and Global Registry of Acute Coronary Events (GRACE) risk score adjusted 30-day mortality.

To date, there has been no investigation of within country provider variation according to the ESC ACCA QIs or the relationship between the QIs and 30-day mortality. To address this knowledge gap, providing an external validation of the ESC ACCA QIs for AMI, we used data from the United Kingdom national heart attack register (Myocardial Ischaemia National Audit Project [MINAP]) which collects data from one health system, the National Health Service of England and Wales.

### Methods

#### Setting and design

The analyses were based on data from MINAP, a comprehensive registry of ACS hospitalizations mandated by the United Kingdom Department of Health.7 Each MINAP entry provides patient demographic data and clinical details of the patient journey across 122 data items; details of MINAP data collection and management have been described previously.7 The analytical cohort (n = 118 075) was drawn from patients (n = 118 168) with a discharge diagnosis of AMI admitted to one of 220 hospitals between 1st January 2012 and 30th June 2013 (see Supplementary material online, Figure S1). Patients were eligible for the study if they were > 18 years of age. For patients with multiple admissions the earliest record was used (to reduce potential bias from previous treatments). We excluded nine hospitals that treated <30 patients within the 18-month period of study. Patient-level data concerning demographics, cardiovascular risk factors, medical history, and clinical characteristics at the time of hospitalization were extracted from the registry. Unique patient identifiers were used to link patients with the Office for National Statistics such that vital status or date of death at 30 days could be ascertained. Data used within the study were fully anonymized and, as such, ethical approval was not required under NHS research governance arrangements. The National Institute for Cardiovascular Outcomes Research (NICOR) which includes the MINAP database (Ref: NIGB: ECC 1-06 (d)/2011) had support, under section 251 of the National Health Service Act 2006, to use patient information for medical research without consent. The study was conducted in compliance with the Declaration of Helsinki.

#### ESC quality indicators

The ESC ACCA position statement defined 7 domains of care encompassing 12 main and 8 secondary QIs (see Supplementary material online, Figure S2). All 20 QIs were mapped to each patient’s MINAP data to identify data fields that would enable their calculation. For each QI, we included patients who were eligible for the treatment or intervention and whose record had no missing data. As such, patients were classified as ineligible if a treatment was contra-indicated, not indicated, not applicable, if the patient declined treatment or treatment was deemed inappropriate due to co-morbidity.

Domain seven specifies the use of an opportunity-based composite score and an all-or-none score (see Supplementary material online, Appendix S1). For this study, we calculated the composite score for each patient and subsequently each hospital, based on the number of times particular care processes were performed (numerator) divided by the number of chances a patient had to receive/hospital had to provide that care (denominator). The composite score was calculated using an equal weight method and included 9 measures (see Supplementary material online, Appendix S1).

### Statistical analyses

Baseline characteristics for the study population were described using numbers and percentages for categorical data, and medians and IQR or means and standard deviations (SD) for continuous non-normally and normally distributed data. For the QIs, the proportion presented is of those eligible for treatment.

We used a validated method for use with MINAP data to calculate each patient’s GRACE risk score. This used the scoring system and coefficients described by the GRACE investigators, given that not all records had information about Killip class and chronic renal failure, the ‘use of loop diuretic’ (as a surrogate for Killip class II-IV), and creatinine concentration, respectively, were added to each patient’s score.8,9

To estimate the GRACE risk score adjusted 30-day mortality, we used the predicted probabilities derived from a logistic regression model where the dependent variable was 30-day mortality and the independent variable was each patient’s calculated GRACE risk score. Data were summarized overall and at the hospital level. We used Spearman’s rank test to investigate the relationship between all combinations of QIs, except for the composite scores because they incorporated several single QIs. We fitted a logistic regression model to assess the strength of association between QI measures and 30-day mortality. For the composite opportunity measure, the performance was split into 4 categories: (1) no interventions received, (2) <40% of eligible interventions received, (3) ≥40% to <80% of eligible intervention received, and (4) ≥80% of interventions received.10,11 We excluded measures that had ≤30 patients with complete data for either aspect of the QI. All analyses were conducted using Stata MP Version 14.0 (StataCorp LP, TX, USA), with statistical significance determined at 5%.

### Results

#### Patient characteristics

Across 211 hospitals in England and Wales, (47 341 [40.1%] STEMI and 70 734 [59.9%] NSTEMI; mean age 68.5 (SD 14.0) years; 33.2% female), there were 37 487 (34.2%) patients with a history of ischaemic heart disease, 24 068 (21.2%) with diabetes, 5,579 (5.1%) with a history of heart failure, and 6678 (6.2%) with chronic renal failure (Table 1). The mean GRACE score was 119.8 (SD 34.1). Following hospitalization, 83 740 (78.2%) received coronary angiography and 2605 (2.5%) coronary artery bypass grafting (CABG). Of STEMI, 21 567 (56.7%) received primary percutaneous coronary intervention [PCI] and of NSTEMI, 23 172 (40.2%) received sub-acute or...
| Demographics | Total cohort \((n = 118,075)\) | Missing data, \(n\), \(\%\) | Hospital variation, mean (SD) or median (IQR) \((n = 211)\) |
|--------------|-------------------------------|-------------------------------|---------------------------------------------|
| Age in years, mean (SD) | 68.5 (14.0) | 63 (0.05) | 69.5 (3.4) |
| Female | 39,088 (33.2) | 352 (0.30) | 34.9 (30.4–38.6) |
| Medical history | | | |
| History of ischaemic heart disease | 37,487 (34.2) | 8491 (7.2) | 36.1 (29.4–40.9) |
| Hypertension | 55,397 (50.6) | 8522 (7.2) | 49.7 (44.1–56.0) |
| Diabetes | 24,068 (21.2) | 4730 (4.01) | 21.6 (17.7–24.4) |
| Dyslipidaemia | 36,890 (34.2) | 10,296 (8.72) | 30.4 (22.6–40.6) |
| Family history of ischaemic heart disease | 28,936 (30.5) | 23,281 (19.7) | 22.1 (16.3–30.8) |
| Smoker (current or previous) | 67,670 (61.4) | 7933 (6.7) | 57.7 (50.4–63.5) |
| Peripheral vascular disease | 4699 (4.3) | 9659 (7.9) | 3.9 (2.6–5.3) |
| Congestive cardiac failure | 5579 (5.1) | 9247 (7.8) | 5.3 (2.9–3.8) |
| COPD | 16,326 (15.0) | 9323 (7.9) | 15.1 (12.1–17.6) |
| Chronic kidney disease | 6678 (6.2) | 9854 (8.4) | 6.1 (3.4–8.7) |
| Cerebrovascular disease | 9070 (8.4) | 9489 (8.0) | 8.2 (5.7–10.9) |
| Clinical Presentation | | | |
| Heart rate at hospitalization, median (IQR), b.p.m. | 78 (66–91) | 18,887 (16.0) | 78 (76–80) |
| Systolic blood pressure at hospitalization, mean (SD), mmHg | 136 (27.8) | 18,794 (15.9) | 139 (5.2) |
| Out of hospital cardiac arrest | 3287 (2.9) | 3737 (3.2) | 1.9 (0.6–3.3) |
| Initial creatinine, median (IQR), \(\mu\)mol/L | 86 (72–107) | 11,622 (9.8) | 87 (83–90) |
| ST-segment deviation on admission | 61,439 (53.5) | 3140 (2.7) | 38.8 (25.8–57.3) |
| Killip class\(^c\) | 36,310 (30.8) | | |
| I | 64,254 (78.6) | | 78.1 (70.6–86.6) |
| II | 11,697 (14.3) | | 14.1% (6.2–21.0) |
| III | 4424 (5.4) | | 5.0 (3.1–8.0) |
| IV | 1390 (1.7) | | 0.6 (0–1.7) |
| GRACE risk score, mean (SD) | 119.8 (34.1) | 33,536 (28.4) | 119.6 (114.3–123.7) |
| In hospital revascularization, (of those eligible) | | | |
| Angiogram\(^b\) | 83,740 (78.2) | 4210 (3.6) | 67.5 (52.7–85.0) |
| PCI | 67,740 (65.6) | 15,388 (13.0) | 45.9 (28.0–73.7) |
| CABG | 2605 (2.5) | 15,388 (13.0) | 1.2 (0.2–3.5) |
| Medications at discharge,\(^d\) | | | |
| Aspirin | 101,591 (98.1) | 1374 (1.2) | 98.7 (96.7–99.6) |
| P2Y\(_{12}\) inhibitor | 92,501 (87.1) | 1434 (1.2) | 89.3 (83.9–93.5) |
| ß-blocker | 86,543 (95.6) | 1412 (1.3) | 96.5 (92.8–98.8) |
| Statin | 84,421 (96.5) | 1275 (1.14) | 96.9 (93.1–98.9) |
| ACEi/ARB | 84,681 (93.9) | 1480 (1.33) | 94.6 (89.5–98.2) |
| Lifestyle advice, | | | |
| Cardiac rehabilitation | 88,302 (81.7) | 4340 (3.7) | 85.5 (70.5–94.9) |
| Smoking cessation advice | 27,848 (74.4) | 2222 (3.3) | 78.0 (54.7–90.5) |
| Dietary advice | 81,745 (77.4) | 7484 (6.3) | 86.5 (55.3–95.9) |

Values presented are given as number (percentage) unless stated.
SD, standard deviation; IQR, interquartile range; IHD, ischaemic heart disease; COPD, chronic obstructive pulmonary disease; GRACE, Global Registry Acute Coronary Events; ACEi/ARB, angiotensin converting enzyme inhibitor/angiotensin II receptor blocker; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting.
\(^a\)History of ischaemic heart disease refers to a history of CABG, MI, PCI, or angina.
\(^b\)Received angiography or PCI.
\(^c\)Killip class: 1: No clinical signs of heart failure, 2: Rales/crackles within the lungs, present \(S\_2\), elevated JVP, 3: frank pulmonary oedema, 4: cardiogenic shock.
\(^d\)Includes eligible patients who started medications during admission.
elective PCI. Hospital variation in patients’ characteristics was small, compared with wider variation in QI attainment (Tables 1 and 2, Figure 1). At 30 days, there were 7063 (7.1%) deaths.

**Domains and quality indicators**

Of the 7 QI domains, MINAP contained data fields for the assessment of all, except the evaluation of patient satisfaction (Table 2). MINAP allowed the assessment of care according to 16 of the 20 QIs; 12 derived directly from corresponding data fields and 4 ascertained indirectly. The remaining 4 quality indicators including, the prescription of high intensity statins at hospital discharge, the recording of the GRACE and CRUSADE risk scores, and patient satisfaction could not be evaluated because MINAP did not collect this information. Figure 1 demonstrates the attainment and variation at a centre level for those QIs measured.

**Domain 1: Centre organization.** Overall, 77.8% (n = 76 099) of eligible patients had pre-hospital interpretation of an ECG, higher than the median value for hospitals 74.8% (IQR 48.6–85.3%). For the remaining components of the main QI and both of the secondary QIs, the level of attainment for patients with AMI was 100% (n = 118 075) (Table 2).

**Domain 2: Reperfusion/invasive strategy.** For STEMI, 89.3% (n = 33 151) received reperfusion <12 h of onset of symptoms, and 74.6% (n = 20 815) received timely reperfusion. (Table 2) The median time from first medical contact with STEMI to wire passage for the whole cohort was 185 (IQR 135–284) min which was similar to the median time for the hospitals, although variation was less (188 min, IQR 170–210 min). For NSTEMI, the performance of coronary angiography was low and varied between hospitals (median, 52.0%, IQR 39.1–73.2%), and 61.3% (n = 17 895) received coronary angiography <72 h of hospitalization.

**Domain 3: In hospital risk assessment.** Only one of the main QIs could be assessed; the assessment of LVEF was recorded in 54.5% (n = 56 680) of eligible patients, and demonstrated suboptimal attainment which varied by hospital (median 54.5%, IQR 32.7–73.2%).

**Domain 4: Antiplatelet treatment during hospitalization.** The prescription of adequate P2Y12 inhibition at discharge was achieved in 87.1% (n = 92 501), but varied across hospitals (median 89.3%, IQR 83.8–93.5%). Fondaparinux use was low (50.3%, n = 30 737) and exhibited the greatest hospital variation (median 66.8%, IQR 0.4–84.7%). However, when fondaparinux or low molecular weight heparin was considered, performance improved and variation reduced (median 90.3%, IQR 84.2–94.6%). The secondary QI found that 88.1% (n = 89 488) of eligible patients with AMI were discharged on dual antiplatelet therapy.

**Domain 5: Secondary prevention discharge treatments.** In total, 96.5% (n = 84 421) of patients eligible for lipid lowering therapy were prescribed a statin at time of discharge from hospital. For the two secondary QIs, 94.2% (n = 31 569) of patients with AMI and heart failure or a LVEF <0.40 received an ACEi or ARB, and 95.8% (n = 32 728) with AMI and heart failure or a LVEF <0.40 received a β-blocker. Hospital attainment was high, but varied between hospitals (IQR 89.1–98.4 and 92.0–99.0, respectively).

**Domain 6: Patient Satisfaction.** The MINAP registry recorded no data about patient satisfaction during the period of study. However, 81.7% (n = 108 110) of patients were referred for cardiac rehabilitation, 77.4% (n = 105 603) received dietary advice and 74.4% (n = 37 443) of current smokers received cessation advice. Across hospitals 85.5% of patients were referred for cardiac rehabilitation (IQR 70.5–94.9), 86.5% of smokers received cessation advice (IQR 54.7–90.5%), and 86.5% were offered dietary advice (IQR 55.3–95.9%).

**Domain 7: Composite quality indicators and GRACE risk score adjusted 30-day mortality.** According to the opportunity-based composite score, patients received 83.3% (n = 118 071) of the interventions for which they were eligible. Hospital attainment was high, but varied between hospitals (median of 82.8%, IQR 77.5–88.7%). For the all-or-none composite score, 83.1% of patients received all of the interventions for which they were eligible which varied more among patients with heart failure or an ejection fraction ≤0.40 than those without (IQR 69.5–87.0 vs. 81.8–93.3). For the cohort, the median GRACE risk score adjusted 30-day mortality was 2.7% (IQR 0.9–8.1%). At the hospital level, variation was limited (median 6.7%, IQR 5.4–7.9%) (Figure 2).

**Correlation of quality indicators**

Overall 39 of the 45 QI to QI combinations demonstrated a weak correlation (Spearman correlation coefficient <0.3), 4 had a significant moderate correlation (0.4–0.7, all P < 0.001) and 2 had a significant strong correlation (≥0.7, all P < 0.001) (Figure 3).

**Quality indicators and mortality**

Eleven QIs had a significant inverse association with 30-day mortality (all P < 0.005) (Figure 4). The association with the greatest magnitude was for high attainment vs. zero attainment of the composite opportunity-based QI (odds ratio [OR] 0.04, 95% confidence interval [CI] 0.04–0.05, P < 0.001). Increasing patient attainment of this indicator from low (OR 0.42 CI 0.37–0.49, P < 0.001) to intermediate (0.15, 0.13–0.16, P < 0.001) to high (0.05, 0.04–0.06, P < 0.001) was significantly associated with a lower risk of 30-day mortality. On average, a unit increase in percentage attainment was significantly associated with a 3% decrease in 30-day mortality (0.97, 0.97–0.97, P < 0.001).

**Discussion**

Using a nationwide clinical database, comprising an analytical cohort of nearly 120 000 patients and over 200 hospitals between 2012–13, we found that the ESC ACCA QIs for AMI allowed the thorough evaluation of AMI care against international standards. The majority of QIs assessed were significantly inversely associated with 30-day mortality, the strongest being a composite indicator which, with increasing attainment, was associated with decreasing rates of death in a dose-response manner. Whilst we found high levels of performance with associated low levels of mortality, there was evidence for between hospital variation in key metrics, which mapped to class 1 guideline-indicated care. As such, the ESC QIs for AMI are applicable and valid, highlighting where in health systems there is potential to improve care and that high levels of performance according to the QIs is likely to reduce unwarranted variation and premature death from AMI.

Data from the EUROASPIRE studies show that the use of evidence-based treatments for AMI and associated outcomes vary
| Domain                          | Quality indicator                                      | Type of quality indicator | Total patients eligible (n) | Proportion receiving care (%) | Hospital variation median % (IQR) (n = 211 hospitals) |
|--------------------------------|---------------------------------------------------------|---------------------------|----------------------------|-------------------------------|------------------------------------------------------|
| 1: Centre organization         | 1.1 Centre organization: part of network               | Main                      | 76 099                     | 77.8                          | 74.9 (48.6–85.3)                                     |
|                                | 1.1a: Single emergency phone number to allow medical    |                           | 118 075                    | 100                           | 100 (100–100)                                       |
|                                | 1.1b: Pre hospital interpretation of the ECG           |                           | 76 099                     | 77.8                          | 74.9 (48.6–85.3)                                     |
|                                | 1.1c: Pre hospital activation of the catheter lab      |                           | 118 075                    | 100                           | 100 (100–100)                                       |
|                                | 1.2: Routine assessment of times to reperfusion        | Secondary                 | 118 075                    | 100                           | 100 (100–100)                                       |
|                                | 1.3: Participate in regular registry                   | Secondary                 | 118 075                    | 100                           | 100 (100–100)                                       |
| 2: Reperfusion/invasive strategy| 2.1: Reperfusion within 12 h of presentation (STEMI)   | Main                      | 33 151                     | 89.3                          | 76.7 (33.3–91.4)                                     |
|                                | 2.2 Timely reperfusion (STEMI)                         | Main                      | 27 892                     | 74.6                          | 66.4 (35.8–78.8)                                     |
|                                | 2.2a: Fibrinolysis received within 30 min (PPCI centres | Main                      | 547                        | 55.0                          | 33.3 (0–60.6)                                        |
|                                | and STEMI patients only)                               |                           |                             |                               |                                                      |
|                                | 2.2b: Primary PCI received within 60 min (PPCI centres | Main                      | 26 358                     | 75.0                          | 69.9 (54.6–80.8)                                     |
|                                | and STEMI patients only)                               |                           |                             |                               |                                                      |
|                                | 2.2c: Primary PCI received within 120 min (non-PPCI    | Secondary                 | 672                        | 93.9                          | 40.0 (0–53.3)                                        |
|                                | centres and STEMI patients only)                      |                           |                             |                               |                                                      |
|                                | 2.2d: Door-in door-out time within 30 min (non-PPCI    | Secondary                 | 538                        | 23.8                          | 5.7 (0–49.6)                                         |
|                                | centres and STEMI patients only)                      |                           |                             |                               |                                                      |
|                                | 2.3: Coronary angiography received within 72 h         | Main                      | 29 199                     | 61.3                          | 52.0 (39.1–73.2)                                     |
|                                | (NSTEMI patients only).                                |                           |                             |                               |                                                      |
|                                | 2.4: Time from diagnosis to wire passage (STEMI),      | Secondary                 | 27 029                     | 185 (135–284)                 | 187.8 (169.8–210)                                   |
|                                | minutes (median, IQR)                                  |                           |                             |                               |                                                      |
| 3: In Hospital risk assessment | 3.1: GRACE risk score recorded in notes                | Main                      | N/A                        | 0                             | N/A                                                  |
|                                | 3.2: CRUSADE risk score recorded in notes              | Main                      | N/A                        | 0                             | N/A                                                  |
|                                | 3.3: LV function recorded in notes                     | Main                      | 104 004                    | 54.5                          | 54.7 (32.7–73.2)                                     |
| 4: Anti thrombotics during      | 4.1: Adequate P2Y12 inhibition on discharge            | Main                      | 106 157                    | 87.1                          | 89.3 (83.8–93.5)                                     |
| hospital                       | 4.2: Fondaparinux received (NSTEMI patients only)      | Main                      | 61 152                     | 50.3                          | 66.8 (0.4–84.7)                                     |
|                                | Fondaparinux or LMWH received (NSTEMI patients only)   | Main                      | 61 185                     | 85.2                          | 90.3 (84.2–94.6)                                     |
|                                | 4.3: DAPT received on discharge                       | Secondary                 | 101 582                    | 88.1                          | 90.5 (85.4–94.1)                                     |
| 5: Secondary prevention        | 5.1: High intensity statins on discharge               | Main                      | N/A                        | 0                             | N/A                                                  |
|                                | 5.2: ACEi/ARB on discharge for those with HF or LVEF < | Secondary                 | 33 531                     | 94.2                          | 95.5 (89.1–98.4)                                     |
|                                | 40                                              |                           |                             |                               |                                                      |
|                                | 5.3: β-blocker on discharge for those with HF or LVEF  | Secondary                 | 34 150                     | 95.8                          | 96.8 (92.0–99.0)                                     |
|                                | <40                                            |                           |                             |                               |                                                      |
| 6: Patient satisfaction        | 6.1 Not applicable                                    | Main                      | N/A                        | N/A                           | N/A                                                  |
| 7: Composite QI                | 7.1 Composite QI (opportunity-based)                  | Main                      | 118 071                    | 83.3 (75.0–100)               | 82.8 (77.6–89.1)                                     |
|                                | 7.2 Composite QI (all-or-none, overall score)         | Secondary                 | 118 075                    | 83.1                          | 84.8 (76.7–90.5)                                     |
|                                | 7.2a Composite QI (all-or-none, 3 measures) (%)       | Secondary                 | 72 648                     | 84.8                          | 88.8 (81.8–93.3)                                     |
|                                | patients with no HF or LVEF≤40                       |                           |                             |                               |                                                      |
|                                | 7.2b Composite QI (all-or-none, 5 measures) (%)       | Secondary                 | 45 427                     | 80.2                          | 79.9 (69.5–87.0)                                     |
|                                | patients with HF or LVEF≤40                         |                           |                             |                               |                                                      |
|                                | 7.3 Mortality rate adjusted for GRACE risk            | Main                      | 84 539                     | 6.9 S.D 10.4                 | 6.7 (5.4–7.9)                                        |

Abbreviations: IQR, interquartile range; ECG, electrocardiogram; STEMI, ST-elevation myocardial infarction; PPCI, primary percutaneous coronary intervention; PCI, percutaneous coronary intervention; NSTEMI, non-ST-elevation myocardial infarction; GRACE, Global Registry Acute Coronary Events; CRUSADE, Can Rapid Risk Stratification of Unstable Angina Patients Suppress ADverse Outcomes with Early Implementation of the ACC/AHA Guidelines; LV, left ventricular; LMWH, low molecular weight heparin; eGFR, estimated glomerular filtration rate; DAPT, dual antiplatelet therapy; ACEi/ARB, angiotensin converting enzyme inhibitor/angiotensin II receptor blocker; QI, quality indicator; HF, heart failure; LVEF, left ventricular ejection fraction; N/A, not applicable.
widely between European countries.\textsuperscript{12–14} Other international comparisons provide evidence for variation both between and within countries.\textsuperscript{1,3,15–17} When there are data to show that adherence to guidelines improves clinical outcomes,\textsuperscript{3,18} variation in healthcare performance against set standards serves as indirect evidence for the potential to modify mortality. Results from our study show that whilst there was variation between hospitals in baseline patient characteristics, qualitatively this was less than that derived for the QIs,
Figure 3 Scatter matrix of European Society Cardiology; Acute Cardiovascular Care Association quality indicators for acute myocardial infarction showing pairwise correlations of all quality indicator pairs, presented alongside Spearman’s rank correlation coefficient (where * indicates $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

Figure 4 Association between the European Society Cardiology; Acute Cardiovascular Care Association quality indicators for acute myocardial infarction and crude 30-day mortality. The composite opportunity QI was divided into the following categories: zero—received no interventions out of those eligible for, low—received <40% of interventions eligible for, intermediate—received ≥40 to <80% of interventions eligible for and high—received ≥80% of interventions eligible for.
suggesting that the provision of treatments may have a greater role in determining outcomes than case mix.19

The association between risk adjusted mortality and the ESC ACCA QIs is consistent with previous findings.10,21 However, this study evaluates a wider spectrum of QIs which map to guidelines and transcends the pathway of AMI care as well as organization of services. Four of the QIs were not associated with a significant reduction in mortality. Coronary angiography <72 h for patients with NSTEMI demonstrated a positive association with mortality. When further investigated, however, the provision of PCI was inversely associated with mortality (OR 0.58, 95% CI 0.51–0.65), in keeping with other evidence.19

We noted many QIs did not correlate with each other, implying they cover the spectrum of the AMI care pathway. The greatest correlation was between the prescription of P2Y12 inhibitors and dual antiplatelet therapy—given that the former is essential for the latter, this is not unexpected. The weakest association was for centre organization and timely angiography in NSTEMI; given that in the United Kingdom centre organization was primarily arranged to treat STEMI, it is not surprising that these two measures did not correlate.

Variation in the delivery of treatments is dependent upon many factors, including the availability of sufficient hospital facilities.1,6,22 a skilled workforce,15,22 high levels of knowledge transfer from scientific studies between healthcare professionals,23 the volume of cases admitted to the hospital,24 differences in the extent to which care is felt to be appropriate,25 as well as uniformity of recommendations from guidelines from different countries.17 Regardless, the latter, we noted that the QI with the widest hospital variation was that for fondaparinux. We speculate this may be because the United Kingdom (2010) guideline for the management of patients with AMI,26 recommended fondaparinux only for cases of AMI who were not going for angiography <24 h of hospitalization—therein differing from current ESC recommendations. The QI with the least variation was centre organization. This is because, in the United Kingdom, emergency care for STEMI is institutionally operationalized as a result of the implementation of a national primary PCI service.22

In North America, there is a well-established program of quality improvement that, for AMI is based upon the ACTION registry29 and allows benchmarking of performance comparisons of providers. For the European community, the ESC AMI QIs offer an opportunity to study and consequently address deficits in care for cardiovascular disease. We demonstrate that this is possible only through a comprehensive clinical registry, as have others,27 but which for several European countries is lacking.1

Although this study has many strengths, we recognize its limitations. The findings are summary measures of performance grounded on patient-level data and described at a hospital level. We followed the ESC AMI QI specification for the calculation of adjusted mortality,4 being mindful that hospital-specific influences were not accounted for in the modelling. Although we excluded hospitals with <30 patients recorded during the study period, for some hospitals in the separate QI analytical cohorts had <30 patients. For the GRACE score, we used surrogates for both Killip class and creatinine in keeping with previous validation work.8,15 MINAP does not record the specific type of statins, so ‘statin prescription’ was used as a surrogate for high intensity statin. Similarly, because there was imperfect recording of Ticagrelor, we used instead receipt of P2Y12 inhibitor.

The recoding, measurement, and reporting of within and between country performance against validated QIs representing class 1 indicated care is the critical next step in the international effort to reduce the burden and variation in premature deaths due to cardiovascular disease across Europe. This study provides good evidence for the application of the ESC ACCA QIs for AMI to clinical registries for the evaluation of cardiovascular care and outcomes; demonstrating their significant inverse association with mortality. Furthermore, this study identified potentially modifiable variation within a high performing health system and sets a road map for the development of standardized data collection in other ESC member countries. Greater and more uniform adherence to guideline-indicated care will result in improved and less varied mortality from AMI.

Supplementary material
Supplementary material is available at European Heart Journal online.

Acknowledgements
TBD and MH were funded by the British Heart Foundation (Project Grant PG/13/81/30474), as a research assistant and research fellow, respectively. The Myocardial Ischaemia National Audit Project (MINAP) is commissioned by the Health Quality Improvement Partnership (HQIP) as part of the National Clinical Audit and Patient Outcomes Programme We gratefully acknowledge the contribution of all hospitals and healthcare professions who participate in the MINAP registry.

Funding
TBD and MH were funded by the British Heart Foundation (Project Grant PG/13/81/30474) as a research assistant and research fellow, respectively.

Conflict of interest: none declared.

References
1. Smith FG, Brogan RA, Alabas O, Laut KG, Quinn T, Bugiardini R, Gale CP. Comparative care and outcomes for acute coronary syndromes in Central and Eastern European transitional countries: a review of the literature. Eur Heart J Acute Cardiovasc Care 2014;3:537–554.
2. Rapsomaniki E, Thuresson M, Yang E, Blin P, Hunt P, Chung S-C, Stogiannis D, Pujades-Rodriguez M, Timmis A, Denaxas SC. Using big data from health records from four countries to evaluate chronic disease outcomes: a study in 114 364 survivors of myocardial infarction. Eur Heart J Qual Care Clin Outcomes 2016;2:172–183.
3. Chung SC, Sundstrom J, Gale CP, James S, Deanfield J, Wallentin L, Timmis A, Jernberg T, Hemingway H. Comparison of hospital variation in acute myocardial infarction care and outcome between Sweden and United Kingdom: population based cohort study using nationwide clinical registries. BMJ 2015;351:h3913.
4. Schiele F, Gale CP, Bonnefoy E, Capuano F, Claeyss MJ, Danchin N, Fox KA, Huber K, Iakobishvili Z, Lettinio M. Quality indicators for acute myocardial infarction: a position paper of the Acute Cardiovascular Care Association. Eur Heart J Acute Cardiovasc Care 2016; doi:10.1177/2048872616643053.
5. Steg PG, James SK, Atar D, Badano LP, Llundqvist CB, Borgar MA, Di Mario C, Dickstein K, Ducrocq G, Fernandez-Aviles F. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Eur Heart J 2012;33:2569–2619.
6. Roffi M, Patrono C, Collet JP, Mueller C, Valgimigli M, Andreotti F, Bax JJ, Borger MA, Brotons C, Chew DP. 2015 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. Eur Heart J 2016;37:3267–3315.
7. Herret E, Smeeth L, Walker L, Weston C. The myocardial ischaemia national audit project (MINAP). Heart 2010;96:1264.
8. Simms AD, Reynolds S, Pieper K, Baxter PD, Cattle BA, Batlin PD, Wilson JI, Deanfield JE, West RM, Fox KA. 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). Eur Heart J 2007; 28:229–233.

9. Laut KG, Gale CP, Pedersen AB, Fox K, Lash TL, Kristensen SD. Persistent geographical disparities in the use of primary percutaneous coronary intervention in 120 European regions: exploring the variation. EuroIntervention 2013; 9:469–476.

10. Laut KG, Gale CP, Pedersen AB, Fox K, Lash TL, Kristensen SD. Determinants and patterns of utilization of primary percutaneous coronary intervention across 12 European countries: 2003–2008. Int J Cardiol 2013; 168:2745–2753.

11. O. Bebb

12. Kotseva K, Wood D, De Bacquer D, De Bacquer D, Pyörälä K, Keil U. Group ES. EUROASPIRE III: a survey on the lifestyle, risk factors and use of cardioprotective drug therapies in coronary patients from 22 European countries. Eur J Cardiovasc Prev Rehabil 2009; 16:121–137.

13. Hall M, Laut T, Alabas O, Brogan R, Gutacker N, Cookson R, Norman P, Timmis A, de Belder M. Patient and hospital determinants of primary percutaneous coronary intervention in England, 2003–2013. Heart 2016; 102:313–319.

14. Widinsky P, Fajadet J, Danchin N, Wijns W. “Stent 4 Life” targeting PCI at all who will benefit the most. EuroIntervention 2009; 4:555–557.

15. Schiele F, Capuano F, Desplanques-Leperre A, Derumeaux G, Thebaut J-F, Gardel C, Grenier C. Hospital case volume and appropriate prescriptions at hospital discharge after acute myocardial infarction: a nationwide assessment. Circ Cardiovasc Quality Outcomes 2013; 6:50–57.

16. Hemingway H, Chen R, Jhungas T, Timmins A, Eldridge S, Black N, Shekelle P, Feder G. Appropriateness criteria for coronary angiography in angina: reliability and validity. Ann Intern Med 2008; 149:221–231.

17. Mcnamara R, Chung S, Jernberg T, Holmes D, Roe M, Timmis A, James S, Deanfield J, Fonarow G, Peterson ED. International comparisons of the management of patients with non-ST segment elevation acute myocardial infarction in the United Kingdom, Sweden, and the United States: the MINAP/NICOR, SWEDEHEART/RIKS-HIA, and ACTION Registry-GWTG/NCDR registries. Int J Cardiol 2014; 175:240–247.

18. Tu JV, Khalid L, Donovan LR, Ko DT. Indicators of quality of care for patients with acute myocardial infarction. Can Med Assoc J 2008; 179:909–915.

19. Hall M, Dondo TB, Yan AT, Goodman SG, Bueno H, Chew DP, Brieger D, Timmis A, Batlin PD, Deanfield JE. Association of clinical factors and therapeutic strategies with improvements in survival following non-ST-elevation myocardial infarction, 2003–2013. JAMA 2016; 316:5073–5082.

20. Bradley EH, Herrin J, Ebel B, McNamara RL, Magid DJ, Nallamothu BK, Wang Y, Normand SL-T, Speruto JA, Krumholz HM. Hospital quality for acute myocardial infarction: correlation among process measures and relationship with short-term mortality. JAMA 2006; 296:72–78.

21. Simms AD, Baxter PD, Cattle BA, Batlin PD, Wilson JI, West RM, Hall AS, Weston CF, Deanfield JE, Fox KA. An assessment of composite measures of hospital performance and associated mortality for patients with acute myocardial infarction. Analysis of individual hospital performance and outcome for the National Institute for Cardiovascular Outcomes Research (NICOR). Eur Heart J Acute Cardiovasc Care 2013; 2:9–18.

22. Hall M, Laut T, Alabas O, Brogan R, Gutacker N, Cookson R, Norman P, Timmis A, de Belder M. Patient and hospital determinants of primary percutaneous coronary intervention in England, 2003–2013. Heart 2016; 102:313–319.

23. Royal College of Physicians. Unstable angina and NSTEMI: early management. In: NICE Guidelines CG94. London: National Institute for Health and Clinical Excellence; 2010.

24. Peterson ED, Roe MT, Rumsfeld JS, Shaw RE, Brindis RG, Fonarow GC, Cannon CP. A call to ACTION (Acute Coronary Treatment and Intervention Outcomes Network): a national effort to promote timely clinical feedback and support continuous quality improvement for acute myocardial infarction. Circ Cardiovasc Quality Outcomes 2009; 2:491–499.