# A nurse-led pre-hospital triage service for identifying patients with occlusive myocardial infarction: a service evaluation

Original research

# A service evaluation of a nurse-led pre-hospital triage service for identifying patients with occlusive myocardial infarction

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## Abstract

**Background/Aims** Acute coronary syndromes include unstable angina and myocardial infarction, of which occlusive myocardial infarction is a high-risk subset that is often missed because of lack of ST elevation. Pre-hospital electrocardiograms may be able to identify myocardial infarction early and reduce mortality**.** However, it is unclear whether pre-hospital electrocardiograms can accurately detect occlusive myocardial infarction and how this effects outcomes. This study will analyse the outcomes of patients with occlusive myocardial infarction who had a pre-hospital electrocardiogram.

**Method** Electrocardiograms transmitted to the coronary care unit triage service were identified, along with data regarding patient demographics, referrals and mortality. Data were analysed for correlations between demographic and clinical factors and type of myocardial infarction.

**Results** A total of 838 electrocardiograms were identified; 69 (8.2%) showed myocardial infarction and eight (1.0%) showed occlusive myocardial infarction, of which 50% had ST elevation. Patients with occlusive myocardial infarction were more likely to be triaged to the coronary care unit than patients with non-occlusive myocardial infarction (*P*=0.04). However, 38 (55.1%) patients with myocardial infarction and four (50.0%) patients with occlusive myocardial infarction were not directed to a coronary care unit or the catheterization laboratory. Patients with occlusive myocardial infarction had higher index episode mortality rates ($P$=0.03) and 30-day mortality rates ($P$<0.01).

**Conclusions** Despite pre-hospital electrocardiogram transmission and adherence to the guidelines, triage of myocardial infarction and occlusive myocardial infarction is imperfect. Refinement of risk scores such and adaptation of new technology is required to help identify patients with occlusive myocardial infarction so they can be prioritised for immediate reperfusion therapy.

**Keywords**

Electrocardiogram, Pre-hospital, Occlusive myocardial infarction, Triage

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## Introduction

Acute coronary syndromes are caused by obstruction of the coronary artery, predominantly by sudden thrombosis of atherosclerotic plaque (Thygesen et al, 2019). Coronary artery occlusion was traditionally assumed to be associated with ST elevation myocardial infarction (STEMI), caused by plaque rupture and thrombosis, often leading to considerable morbidity and mortality (Ibanez et al, 2018). Rapid reperfusion is vital in the case of an occlusive myocardial infarction because of the sudden blockage of arterial blood flow by thrombotic clot. STEMI requires immediate reperfusion therapy, such as percutaneous coronary intervention or thrombolysis (National Institute for Health and Care Excellence, 2020).

Despite this, around one-quarter of patients who do not show ST elevation on electrocardiogram have coronary artery occlusion, an occlusive myocardial infarction (Khan et al, 2017). Certain electrocardiogram findings, such as hyperacute T waves (prominent, symmetrical T waves in the precordial leads), De-Winters syndrome (ST depression and peaked T waves in the precordial leads) or Wellens syndrome (ST depression and peaked T waves in the precordial leads) can indicate critical ischaemia (Aslanger et al, 2021). On an electrocardiogram, ischaemia is a dynamic process illustrated by left anterior descending artery occlusion with evolution from precordial hyperacute T waves to De Winters, often with further evolution to ST elevation (Verouden et al, 2009). Conversely, ST elevation, the traditional marker of acute coronary occlusion, can often represent alternative pathology, such as normal variant, left ventricular hypertrophy and pericarditis with widespread saddle-shaped ST elevation (Huang and Birnbaum, 2011).

The lack of absolute correlation between ST elevation on the electrocardiogram and occlusive myocardial infarction suggests that awareness of alternate electrocardiogram signs of occlusive myocardial infarction are crucial. The importance of precordial T-waves in left anterior descending occlusion are becoming increasingly appreciated, but the identification of occlusive electrocardiogram patterns without ST elevation are not fully outlined in the current guidelines (O’Gara et al, 2013; Ibanez et al, 2018). However, the guidelines do state that urgent reperfusion therapy should be considered in patients with myocardial infarction or those who experiencing ongoing pain, even if the signs do not show on their electrocardiogram, as a fail-safe to include potentially critical patients (O’Gara et al, 2013; Ibanez et al, 2018).

Lack of ST elevation in occlusive myocardial infarction is associated with a delay in reperfusion therapy and poorer mortality outcomes compared to patients with ST elevation or nonocclusion (Khan et al, 2017). Left anterior descending occlusion is especially associated with high mortality, making early accurate recognition vital (Entezarjou et al, 2018).

Performing an electrocardiogram before the patient arrives at the hospital can help with diagnosis and lead to improved outcomes in chest pain management (Quinn et al, 2014). Transmission of the pre-hospital electrocardiogram to a dedicated specialist unit can also improve door-to-balloon time and reduce mortality rates (Marcolino et al, 2019). A prehospital electrocardiogram can be transmitted to a specialist cardiac centre for analysis, often by trained cardiac nursing staff (Rushworth et al, 2014). However, the diagnosis can be difficult because of the heterogenicity of electrocardiogram findings, which are compounded by artefacts (eg skeletal muscle contraction) and bias, such as anchoring (overly-relying on the first piece of information) or confirmation (favouring information to confirm existing ideas) (Cairns et al, 2017). Risk stratification systems, such as the global registry of acute coronary events (GRACE) and HEART (comprised of history, electrocardiogram, age, risk factors and troponin) can be accurate approaches to identifying critical patients, and are thus recommended in guidelines. Yet, they are limited in the prehospital environment because they require cardiac biomarkers and, in the case of the GRACE system, creatinine measurement (Elbarouni et al, 2009; Mahler et al, 2015). Blood tests are also difficult to obtain promptly when time is critical, as is the case in occlusive myocardial infarction. Therefore, in the prehospital environment, greater emphasis is placed on the patient's symptoms, signs and comorbidities, as well as the electrocardiogram.

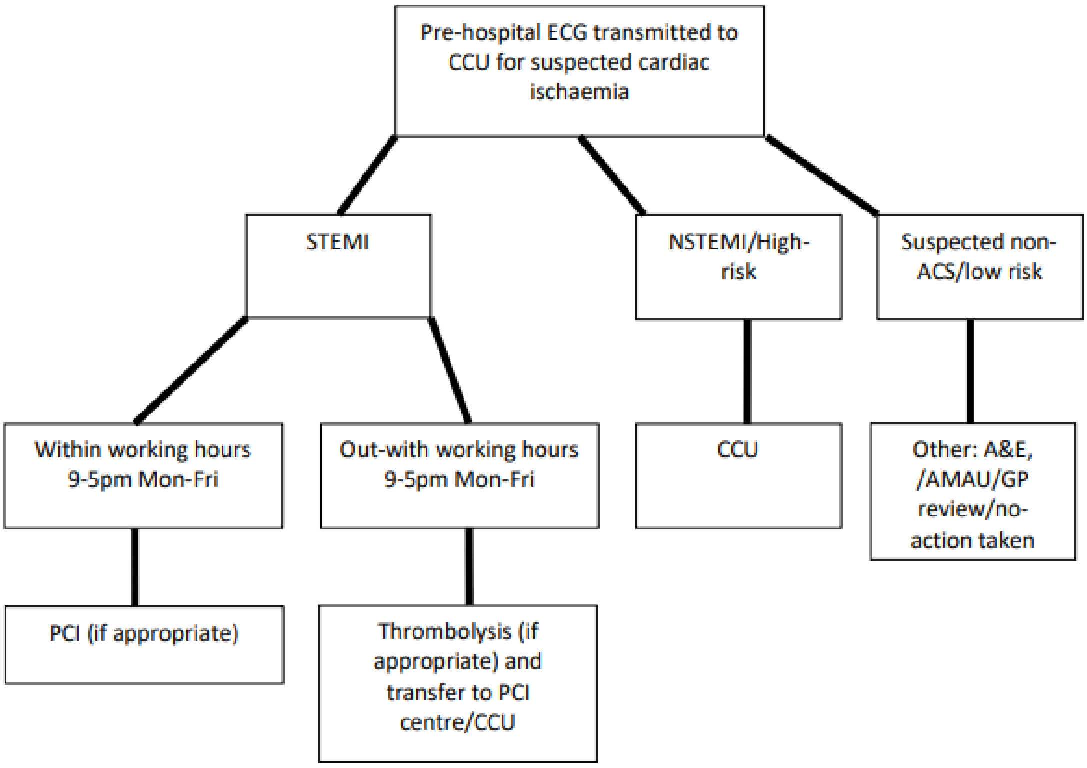
Therefore, while the use of prehospital electrocardiograms for the identification of STEMI can be beneficial, the diagnosis remains challenging, which can lead to patients without ST elevation who have occlusive myocardial infarction receiving suboptimal therapy (Khan et al, 2017). The aim of this retrospective study was to assess whether a coronary care unit nurse-supported prehospital electrocardiogram triage service was able to accurately identify and appropriately triage those with acute occlusive myocardial infarction.

## Methods

This was a single-centre, retrospective cohort study that analysed data from a nurse-led triage and electrocardiogram decision support service, based at a rural regional hospital in Scotland. The hospital covers a large geographical area (32,500 km$^2$), with a dispersed population of approximately 250,000 people, and provides a tertiary cardiology service to several secondary district hospitals. Because of the hospital's geography, a large proportion of patients with STEMI live more than 2 hours away from a centre that can provide percutaneous coronary intervention. In these cases, thrombolysis is offered, then patients are transferred.

Prehospital electrocardiograms of patients with suspected myocardial infarction are emailed to the service from practitioners such as ambulance crews or primary care physicians. Electrocardiograms are also transmitted to the nurse-led triage service from district hospitals, which lack specialist cardiac services. Because of the lack of specialist cardiac services in these outlying areas, the transmission of electrocardiograms is encouraged for any suspected myocardial infarction, along with other symptoms, such as palpitations or collapse. Submitted electrocardiograms are analysed by a trained coronary care nurse who has access to patient electronic records, including any previous electrocardiogram records. If a prehospital electrocardiogram fulfils the European Society of Cardiology diagnostic criteria for STEMI (Ibanez et al, 2018) and the patient has a history suggestive of cardiac disease, then transportation of the patient to a primary percutaneous coronary intervention centre or thrombolysis will be recommended, dependent on the patient's location and the availability of a catherisation laboratory. If the electrocardiogram is not suggestive of STEMI but a combination of symptoms, risk factors, haemodynamic stability or other non-diagnostic electrocardiogram changes are present, then a decision will be made regarding whether the patient should be prioritised for immediate reperfusion therapy.

Figure 1. Flow-chart outlining the triage system for prehospital electrocardiogram transmitted to coronary care centre.




For the purpose of this analysis, electrocardiograms were only included if the reason for transmission was a suspected myocardial infarction. Data were collected from the prehospital setting, including patient age, gender, location of event, distance from hospital and electrocardiogram findings. Data regarding the final diagnosis, index admission survival, 30-day survival and 1-year survival were obtained from the patients' electronic medical records. Angiographic records were analysed for reports of acute coronary occlusion. If occlusion was identified, the angiographic images were verified with a second interventional cardiologist for validation.

Data were analysed using the Statistical Package for the Social Sciences (version 25). Crosstabs with Pearson Chi-squared testing and logistic regression were used to determine odds ratios, 95% confidence intervals and significance for categorical variables. Fisher's exact test was used when appropriate, and independent sample *t*-test were used to determine statistical significance for continuous variables. A *P* value of less than 0.05 was considered significant.

Ethical approval for this service evaluation was provided by the University of the Highlands and Islands research ethics committee (OL–ETH SHE–271). Caldicott approval was also obtained.

## Results

### Baseline demographics and triage

A total of 838 electrocardiograms were emailed to the service between 1 January and 31 July 2017. A diagnosis of myocardial infarction was present in 69 (8.2%) cases, while a non-myocardial infarction diagnosis was present in 694 (74.5%) cases and 75 (8.9%) cases had missing data regarding diagnosis. Of the 838 patients, 498 (59.4%) were men and 340 (40.6%) were women. Patients with myocardial infarction were likely to be older than those who did not have myocardial infarction (72.9 years vs 67.5 years, *P*=0.01).

Of the 69 patients with myocardial infarction, eight (11.6%) were found to have an occlusive myocardial infarction on subsequent angiography, 52 (75.4%) did not have any acute occlusion on angiography or were judged not fit enough to undergo an angiogram, and nine (13.0%) had missing data on angiographic outcomes. Details regarding patient demographic and symptoms comparing patients with myocardial infarction compared to those without myocardial infarction are shown in Table 1, while Table 2 shows these data comparing patients with occlusive myocardial infarction compared to those with non-occlusive myocardial infarction. As expected, patients with myocardial infarction were significantly more likely to experience chest pain compared to patients without myocardial infarction (odds ratio=7.34, *P*<0.01, confidence interval=3.14–17.33). Patients whose presenting symptoms was collapse were more likely to have a non-myocardial infarction diagnosis (odds ratio=0.14, *P*=0.01, confidence interval=0.03–0.56). However, there were no statistical differences between occlusive and non-occlusive myocardial infarction relating to demographics or symptoms.

**Table 1.** Demographics, clinical circumstances and outcomes of patients with and without myocardial infarction

| **Characteristic** | **Total** (*n*=838) | **No myocardial infarction** (*n*=694) | **Myocardial infarction** (*n*=69) | **Odds ratio** |
|---|---|---|---|---|
| Mean age (years) | 67.6 | 67.5 | 72.9 | *P*=0.01 |
| Male gender (%) | 498 (59.4) | 454 (59.0) | 45 (65.2) | 1.23 (*P*=0.42 CI 0.74–2.06) |
| Mean distance from hospital (miles) | 46.2 | 46.4 | 45.3 | 0.99 (*P*=0.88 CI 0.99–1.01) |
| **Presenting symptoms (%)** | | | | |
| Chest Pain | 454 (54.2) | 371 (53.5) | 58 (84.1) | 7.34 (*P*<0.01 CI 3.14–17.33)* |
| Breathlessness | 124 (14.8) | 101 (14.6) | 15 (21.7) | 1.68 (*P*=0.10 CI 0.91–3.10) |
| Collapse | 138 (16.5) | 126 (18.2) | 2 (2.9) | 0.14 (*P*=0.01 CI 0.03-0.56)* |
| Palpitations | 57 (6.8) | 49 (7.1) | 3 (4.3) | 0.61 (*P*=0.41 CI 0.18–2.01) |
| **Referrer (%)** | | | | |
| Ambulance | 747 (89.1) | 611 (88.7) | 67 (97.1) | 4.28 (*P*=0.04 CI 1.03–17.8)* |
| GP | 60 (7.2) | 56 (8.1) | 1 (1.4) | 0.17 (*P*=0.08 0.23–1.22) |
| Other hospital | 23 (2.7) | 19 (2.8) | 1 (1.4) | 0.52 (*P*=0.53 CI 0.07–3.93) |
| Other (eg police) | 3 (0.4) | 3 (0.4) | 0 (0.0) | n/a |
| No data recorded | 5 (0.6) | 5 (0.7) | 0 (0.0) | n/a |
| **Triage location (%)** | | | | |
| Emergency department/local hospital | 363 (43.3) | 328 (47.3) | 35 (50.7) | 1.10 (*P*=0.76 CI 0.60–2.02) |

| | | | | |
|---|---|---|---|---|
| Acute medical assessment unit | 23 (2.7) | 20 (2.9) | 3 (4.3) | 1.50 (*P*=0.53 CI 0.43–5.23) |
| GP | 59 (7.0) | 58 (8.4) | 1 (1.4) | 0.16 (*P*=0.07 CI 0.02–1.15) |
| Catheter laboratory | 2 (0.2) | 0 (0.0) | 2 (2.9) | n/a |
| Coronary care unit | 7 (0.8) | 4 (0.6) | 3 (4.3) | 7.33 (*P*=0.01 CI 1.60–33.71)* |
| Remained at current location | 18 (2.1) | 18 (2.6) | 0 (0.0) | n/a |
| Other (eg other hospital/surgical receiving/police custody) | 91 (10.9) | 83 (12.0) | 8 (11.6) | n/a |
| No data recorded | 275 (32.8) | 258 (37.2) | 17 (24.6) | 1.06 (*P*=0.90 CI 0.50–2.34) |
| **Outcomes** | | | | |
| Admitted | 469 (56.0) | 401 (57.8) | 68 (98.6) | 49.98 (*P*<0.01 CI 6.90–362.01)* |
| Episode mortality (%) | 91 (10.9) | 13 (1.9) | 2 (4.3) | 1.81 (*P*=0.35 CI 0.52–6.34) |
| 30-day mortality (%) | 34 (4.1) | 26 (3.7) | 8 (11.6) | 3.72 (*P*<0.01 CI 1.60–8.65)* |
| 1-year mortality (%) | 106 (12.6) | 89 (12.2) | 17 (24.6) | 2.360 (*P*<0.01 CI 1.30–4.28)* |
| ***Significant at *P*<0.05; CI=confidence interval | | | | |

**Table 2.** Demographics, clinical circumstances and outcomes of patients with occlusive and non-occlusive myocardial infarction

| | **Total** (*n*=60) | **Nonocclusive myocardial infarction** (*n*=52) | **Occlusive myocardial infarction** (*n*=8) | **Odds ratio** |
|---|---|---|---|---|
| Mean age (years) | 69.65 | 70.15 | 66.38 | *P*=0.41 |
| Male gender | 39 (65.0) | 28 (53.8) | 7 (87.5) | 4.38 (*P*=0.18 CI 0.26–1.99) |
| Mean distance from hospital (miles) | 59.79 | 54.9 | 60.2 | 1.01 (*P*=0.44 CI 0.99–1.03) |
| Fulfils criteria for STEMI* | 13 (21.7) | 9 (17.3) | 4 (50.0) | 0.28 (*P*=0.11 CI 0.58–1.35) |
| **Complaint (%)** | | | | |
| Chest pain | 48 (80.0) | 34 (82.9) | 6 (75.0) | 0.71 (*P*=0.78 CI 0.71–7.20) |
| Breathlessness | 12 (20.0) | 10 (19.2) | 2 (25.0) | 1.48 (*P*=0.67 CI 0.25–8.80) |
| Collapse | 4 (6.7) | 4 (7.7) | 0 (0) | 1.09 (*P*=0.42 CI 1.00–1.19) |
| Palpitations | 3 (5.0) | 3 (5.7) | 0 (0) | 1.07 (*P*=0.49 CI 0.99–1.15) |
| **Referrer (%)** | | | | |

| | | | | |
|---|---|---|---|---|
| Ambulance | 48 (80.0) | 41 (78.8) | 7 (87.5) | 0.137 (*P*=0.18 CI 0.01–2.45) |
| GP | 2 (3.3) | 1 (2.9) | 1 (12.5) | 7.29 (*P*=0.77 CI 0.41–130.07) |
| Other hospital | 0 (0.0) | 0 (0.0) | 0 (0.0) | n/a |
| Other (eg police) | 0 (0.0) | 0 (0.0) | 0 (0.0) | n/a |
| No data recorded | 0 (0.0) | 0 (0.0) | 0 (0.0) | n/a |
| **Triage location (%)** | | | | |
| Emergency department/local hospital | 23 (38.3) | 22 (42.3) | 1 (12.5) | 0.06 (*P*=0.01 CI 0.01–0.52)** |
| Acute medical assessment unit | 2 (3.3) | 1 (1.9) | 1 (12.5) | 3.17 (*P*=0.38 CI 0.25–40.56) |
| GP | 1 (1.7) | 1 (1.9) | 0 (0.0) | 7.29 (*P*=0.18 CI 0.41–130.07) |
| Catheterisation laboratory | 2 (3.3) | 0 (0.0) | 2 (25.0) | n/a |
| Coronary care unit | 2 (3.3) | 0 (0.0) | 2 (25.0) | 15.6 (*P*=0.04 CI 1.19–204.78)** |
| Remain at current location | 1 (1.7) | 1 (1.9) | 0 (0.0) | n/a |
| Other (other hospital/police custody) | 6 (10.0) | 5 (9.6) | 1 (12.5) | 0.90 (*P*=1.17 CI 0.12–11.81) |
| No data recorded | 12 (20.0) | 11 (26.8) | 1 (12.5) | 1.17 (*P*=0.90 CI 0.12–11.81) |
| **Outcomes (%)** | | | | |
| Admitted | 59 (98.3) | 51 (98.1) | 8 (100) | 1.020 (*P*=0.70 CI 0.98–1.06) |
| Episode mortality | 2 (3.3) | 0 (0.0) | 2 (25) | 17 (*P*=0.03 CI 1.33-216.70)** |
| 30-day mortality | 2 (3.3) | 0 (0.0) | 2 (25) | 9.33 (p < 0.01 CI 4.38-19.88)** |
| 1 year mortality | 7 (11.7) | 5 (9.6) | 2 (25) | 2.44 (*P*=0.32 CI 0.40–15.00) |
| * as defined by fourth universal definitions of myocardial infarction (Thygesen et al, 2019); **=significant at *P*<0.05; CI=confidence interval; STEMI=ST-elevation myocardial infarction | | | | |

## Referral and triage

Patients' source of referral and location of triage are shown in *Tables 1* and 2. Most patients with myocardial infarction (*n*=38, 55.1%) and three patients with occlusive myocardial infarction (37.5%) were directed to the emergency department or an acute medical assessment unit, rather than coronary care unit or catherization laboratory. Patients with myocardial infarction were more likely to be referred by ambulance (odds ratio=4.28, *P*=0.04, confidence interval=1.03–17.8) and to go straight to the coronary care unit (odds ratio=7.33, *P*=0.01, confidence interval=1.60–33.71) than those without myocardial infarction. Patients with occlusive myocardial infarction were less likely to attend the emergency department (odds ratio=0.06, *P*=0.01, confidence interval=0.01–0.52) than those with non-occlusive myocardial infarction. However, patients with occlusive myocardial infarction were more likely to go straight to the coronary care unit than those with non-occlusive myocardial infarction (odds ratio=15.6, *P*=0.04, confidence interval=1.19–204.78). Only two patients with occlusive myocardial infarction were directed for immediate percutaneous coronary intervention and two to a coronary care unit, meaning that 50% of patients with critical occlusive myocardial infarction and non-diagnostic electrocardiograms were triaged to non-cardiac specialist areas, such as the emergency department and acute medical wards.

### Outcomes

Admission and mortality outcomes are shown in in *Tables 1 and 2*. Patients with myocardial infarction did not have a higher mortality than patients without non-myocardial infarction during the index episode (odds ratio=1.81, *P*=0.35, confidence interval=0.52–6.34), but they did have a higher 30-day mortality rate (odds ratio=3.72, *P*<0.01, confidence interval=1.60–8.65) and 1-year mortality rate (odds ratio=2.36, *P*<0.01, confidence interval=1.30–4.28 respectively). Patients with an occlusive myocardial infarction had a significantly higher index episode mortality rate (odds ratio=17.00, *P*=0.03, confidence interval=1.33–216.70) and 30-day mortality rate (odds ratio=9.33, *P*<0.01, confidence interval=4.38–19.88) compared to patients with non-occlusive myocardial infarction, but there was no such different in 1-year mortality (odds ratio=2.44, *P*=0.32, confidence interval=0.40–15.00).

## Discussion

The prehospital electrocardiogram triage service was able to accurately identify acute coronary syndrome in 98.6% of patients with myocardial infarction for whom admission was recommended, and with the one exception being a patient whose data on referral location was missing. The numbers of patients with occlusive myocardial infarction are very small (*n*=8), yet 50% of patients in this group were not directed straight to the catheterization laboratory or coronary care unit. Although the reasons for this are not clear, it is likely related to the increased difficulties associated with identifying occlusive myocardial infarction, as only 50% of patients with this condition had ST elevation on electrocardiogram.

A high number of patients, both with and without myocardial infarction, were admitted. It is likely that a high number of non-myocardial infarction diagnoses would have required hospital admission, but it could be possible that a proportion of patients might have had benign, non-cardiac chest pain and, therefore, not required hospital admission. This creates an opportunity for a potential 'rule-out' algorithm that could identify these patients in the prehospital environment and prevent an unnecessary hospital admission or transfer. Conversely, a high proportion of cases that were later diagnosed as a myocardial infarction were triaged to the emergency department or acute medical assessment ward, meaning that these patients were not streamlined straight to the coronary care unit or the catherisation laboratory. This suggests that any rule-out algorithm should be treated with much caution.

In the index episode, there was no significant difference in mortality between patients with and without myocardial infarction. However, patients with myocardial infarction did have a higher 30-day and 1-year mortality rate, which is in keeping with research regarding long-term mortality rates from myocardial infarction (McManus et al, 2011). Patients with occlusive myocardial infarction had a higher index episode mortality rate than those with non-occlusive myocardial infarction, which is likely a result of the increased cardiac instability from total coronary occlusion compared to partial occlusion (Wang et al, 2009). The present study found increased mortality rates among patients with occlusive myocardial infarction at 30 days, but not at 1 year. This trend is similar to the common STEMI patient mortality pattern, as this subset of patients is usually younger with fewer comorbidities, so if they survive the initial index episode and potential complications, they have better outcomes than patients with non-ST elevation myocardial infarction, who are often older and more frail (McManus et al, 2011; Ibanez et al, 2018).

Previous evidence has shown that triaging patients to dedicated centres for heart attacks can significantly improve survival rates, most likely as a result of decreased call-to-balloon time (Rathod et al, 2018). Although patient numbers in the present study were small, those with occlusive myocardial infarction were significantly more likely to be sent straight to dedicated cardiology centres, with 25% being directed straight to the cardiac catherisation laboratory and 25% to the coronary care unit. However, there is still scope for improvement, as two patients with occlusive myocardial infarction were admitted to the emergency department, which could lead to a potential delay in cardiac reperfusion and potentially poorer outcomes (Scholz et al, 2018).

The potential of electrocardiogram analysis for identification of occlusive myocardial infarction has been shown in previous research, with emphasis is placed on signs of occlusive myocardial infarction rather than traditional STEMI criteria (Aslanger et al, 2020). Adoption of risk assessment scores, such as the GRACE score, as advocated by the National Institute for Health and Care Excellence (2020) guidelines, or categorisation of very high-risk patients, as defined by the European Society of Cardiology guidelines, could help to identify a selection of patients with occlusive myocardial infarction without ST elevation (National Institute for Health and Care Excellence, 2020; Collet et al, 2020**).** However, there is no evidence for the use of risk scores as a method for the stratification of occlusive myocardial infarction compared to non-occlusive myocardial infarction. Furthermore, scores such as GRACE require blood results, including cardiac markers and creatinine, which could be difficult to obtain in the prehospital environment, or in a time critical environment where urgent reperfusion is required, as in occlusive myocardial infarction.

Additional potential refinements to prehospital triage include the adoption of algorithms, such as clinical decision support systems and deep-learning neural networks to improve diagnostic accuracy by guiding prehospital practitioners (Smith et al, 2019**;** Knoery et al, 2020). Clinical decision support systems can improve prehospital identification of myocardial infarction through a potential combination of clinical symptoms, signs, risk factors, prehospital biomarkers and computer electrocardiogram analysis, which could help to develop ‘rule-in’ algorithms (Knoery et al, 2020). Electrocardiogram interpretation can also be assisted by computer analysis to provide enhanced decision making for the cardiac nurse activator (Kashou et al, 2020). Deep-learning neural network electrocardiogram analysis has shown significantly higher specificity and positive predictive value for myocardial infarction compared to standard machine learning or rule-based symbolic algorithms **(**Smith et al, 2019**).** Neural networks can also reduce the number of unnecessary transmissions of electrocardiograms to specialist centres (Forberg et al, 2012).

## Limitations

There are several limitations that potentially influence the validity of this study. Although clinical staff and computer electrocardiogram algorithms are highly trained in the identification of traditional myocardial infarction features, there is the chance that they may have some doubt (with associated delay in treatment) about some of the more unfamiliar electrocardiogram subtleties that indicate occlusive myocardial infarction (Verouden et al, 2009). Refinements of prehospital algorithms, specifically for occlusive myocardial infarction, could be tested to see if prehospital electrocardiogram transmission is an effective method for identification of occlusive myocardial infarction for urgent reperfusion therapy.

In addition, this analysis was carried out at a coronary care unit with a mixture of centrally-based and remotely-based patients. Previous analysis has found poorer outcomes for patients in more remote locations, which could be an additional confounding factor affecting mortality analysis (Kamona et al, 2018). However, the purpose of prehospital electrocardiogram analysis is to help streamline the identification of such critical patients at higher mortality and help mitigate the impact of remote geography in treating such patients.

Previous research has found that patients with occlusive myocardial infarction on first medical contact had either fully or partially resolved by the time they underwent angiography, as coronary artery occlusion is a dynamic process (Libby and Theroux, 2005). Therefore, a proportion of the patients who were categorized as having non-occlusive MI on their discharge diagnosis could potentially have been re-categorised as occlusive, depending on their initial electrocardiogram, and have had the associated cardiac ischaemia. It is important to identify patients with dynamic changes on their electrocardiogram, as there is no guarantee that their coronary artery occlusion will resolve spontaneously; the problem may return and have a prolonged period of cardiac ischaemia before resolution. Therefore, it is vital that these patients are considered for urgent reperfusion therapy, such as percutaneous coronary intervention or thrombolysis, especially if they are experiencing ongoing pain (Ibanez et al, 2018).

Finally, this study is limited by the low numbers of patients with occlusive myocardial infarction identified. This may indicate that occlusive myocardial infarction is a relatively uncommon finding, or that the majority of occlusion partially resolves itself by the time of angiography. However, the combination of low numbers and a large amount of missing data hindered statistical analysis. Ideally, further analysis would have focused on comparing the outcomes of patients with STEMI with those of patients with occlusive myocardial infarction, as not all of the latter present with STEMI and this subset is likely to have worse outcomes, thought to be a result of delays in identification (Khan et al, 2017).

## Conclusions

Prehospital electrocardiogram transmission to a specialist unit has the potential to improve early identification of myocardial infarction, yet remains imperfect for triaging patients with critical myocardial infarction and occlusive myocardial infarction to the correct locations. An algorithm may help to identify patients with occlusive myocardial infarction, particularly in the absence of ST elevation, so that this subset of patients can be prioritised for immediate reperfusion therapy. With increased education and a shift towards digitalization, with the potential incorporation of diagnostic algorithms, new technologies could be the key to identifying the subtleties of occlusive myocardial infarction.

## Key points

- Occlusive myocardial infarction carries the highest risk of death, but can present without ST elevation.
- Coronary care unit nurses and catheter laboratory activators should be aware of occlusive myocardial infarction without ST elevation.
- Despite best efforts, occlusive myocardial infarction can be missed, leading to delays in accessing urgent, life-saving reperfusion therapy.
- Revised pathways, deep-learning neural networks of electrocardiogram interpretation and novel biomarkers might offer improved triage in the future.

## Reflections

- Could the patient pathway in your centre be improved?
- Are staff in your centre trained to recognise STEMI equivalent electrocardiograms?
- Is there robust prehospital support for ambulance crews and primary care in your centre?
- Could cardiac nurses play a role in improving support?

## Conflicts of interest

The authors declare that there are no conflicts of interest.

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