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Impact of paramedic education on door-to-balloon times and appropriate use of the primary PCI pathway in ST-elevation myocardial infarction

Kalaivani Mahadevan [ORCID],[1] Divyesh Sharma,[2] Christopher Walker,[1] Annette Maznyczka,[1] Alex Hobson,[1] Philip Strike,[1] Huw Griffiths,[1] Ali Dana[1]

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[1]Department of Cardiology, Portsmouth Hospitals University NHS Trust, Portsmouth, UK
[2]Department of Cardiology, Altnagelvin Hospitals Health and Social Services Trust, Londonderry, UK

Correspondence to
Dr Ali Dana;
ali.dana@porthosp.nhs.uk

ABSTRACT

Objective Evidence supports improved outcomes and reduced mortality with rapid reperfusion through primary percutaneous coronary intervention (PPCI) for ST-elevation myocardial infarction (STEMI). UK national audit data (Myocardial Ischaemia National Audit Project [MINAP]) demonstrates minor improvements in door-to-balloon times (DTB) of <90 min but increasing call-to-balloon times (CTB). We evaluate the effect of a regional Cardiologist delivered paramedic education programme (PEP) on DTB times and appropriate use of the PPCI pathway.

Methods This was a prospective single-centre study of patients with STEMI brought directly to hospital via ambulance services. Data sources included ambulance charts, in-patient notes, British Cardiovascular Interventional Society (BCIS) database and local MINAP data. All DTB breaches were investigated. A local PEP was implemented with focus on ECG interpretation, STEMI diagnosis and appropriate use of the PPCI pathway. Non-parametric Wilcoxon rank test was used for comparisons of DTB and CTB times between direct versus ED-associated cath lab transfer.

Results A total of 728 patients with STEMI were admitted directly to our centre via ambulance, 66% (n=484) directly to the Catheterisation Laboratory (Cath Lab) and 34% (n=244) via the Emergency Department (ED). There was a significant increase in median DTB, 83 vs 37 min (p<0.001) and median CTB 144 vs 97.5 min (p<0.001) when transfer to the Cath Lab occurred via the ED versus direct transfer. The PEP increased direct cath lab transfers (52%–85%) and generated annual reductions in median DTB times, with sustained improvement seen throughout the 7-year study period.

Conclusions Paramedic education increases direct transfer of STEMI patients to the Cath Lab, and reduces DTB times. This is an effective and reproducible intervention to facilitate timely reperfusion in STEMI.

Strengths and limitations of this study

- This is the first study to assess the effects of a Cardiologist delivered paramedic education programme on door-to-balloon times through effective and appropriate use of the primary percutaneous coronary intervention (PPCI) care pathway for ST-elevation myocardial infarction.
- Data demonstrate consistent long-term improvements in regional ST-elevation myocardial infarction care - this programme is reproducible to PPCI networks across the UK.
- This was a single-centre observational study - heterogeneity of local infrastructure and delivery of secondary care may limit generalisability of these results.
- The study does not account for potential changes in the core delivery of paramedic education and training which may have confounded final results.
- It was not feasible to measure the exclusive and direct effect of the paramedic education programme on call-to-door time, which has been shown to be a continuously increasing component of call-to-balloon time in the UK.

BACKGROUND

Primary percutaneous coronary intervention (PPCI) is the recognised optimal strategy for treatment of ST-segment elevation myocardial infarction (STEMI).[1–7] Superiority of timely PPCI over fibrinolysis has been repeatedly demonstrated in randomised controlled trials.[8–14] Our unit's 24/7 PPCI service was launched in 2010, with STEMI patients routinely receiving pre-hospital thrombolysis and subsequent transfer to the emergency department (ED) prior to this date. ECG transmission to our coronary care unit (CCU) is facilitated by Mobimed or Lifenet. All cases of suspected STEMI as well as those where diagnostic uncertainty exists are reviewed by and/or discussed with the on-call interventional cardiologist who makes the final decision to accept a patient directly for emergency cardiac catheterisation.

The logistical complexities of the PPCI pathway render it fallible to treatment delays including both pre-hospital and in-hospital. Guidelines advocate a target of <90 min from first medical contact (FMC) to reperfusion for STEMI in the community and <60 min if first diagnosed in a PPCI-capable centre.[15] Minimising 'system delay' between FMC and reperfusion is paramount to improving patient outcomes and survival in STEMI patients, as demonstrated in the FIT-STEMI trial, whereby every 10 min delay from FMC to reperfusion led to a 3.3% increase in mortality.[16] Early recording, recognition and transmission of ECG by ambulance personnel is crucial to facilitating direct transfer of patients to a PCI-capable centre and bypassing the ED to minimise system delays.[17–21] Successive reports published by the Myocardial Ischaemia National Audit Project (MINAP) have indicated that in contrast to minor improvement in median door-to-balloon (DTB) times, median call-to-balloon (CTB) times have been consistently increasing in recent years; the total % of patients successfully receiving PPCI with a CTB of <150 min decreasing from 86.3% in 2012 to 70.7% in 2018.[22]

Portsmouth Hospitals University NHS Trust is a large acute hospital trust, serving a population of over 1.2 million, and has been a PPCI centre since September 2010, performing approximately 400 PPCI procedures annually. In addition to data submission to the national audit databases, we have prospectively monitored and recorded primary quality indicators for all PPCI cases including CTB and DTB times, investigating breaches of gold-standard targets, and actively implementing initiatives aimed at improving optimal adherence to the PPCI pathway. One such initiative, aimed at facilitating rapid recognition of STEMI in the community and encouraging direct patient transfer to the Cath Lab, has involved a series of 1-day educational courses for paramedics and ambulance personnel. In this study, we evaluate the impact of the paramedic educational programme (PEP) on DTB times and appropriate use of the PPCI pathway.

METHODS

Population

All patients with suspected STEMI, based on clinical presentation and ECG changes, admitted between February 2011 and February 2014, were initially included in this study. To ensure the focus of the study was directly on the impact of the PEP on DTB times, and to eliminate confounding or bias, we excluded the following groups from further analysis: self-presenters to ED, patients transferred from local non-PCI centres, those who developed ST elevation while in hospital and those requiring initial resuscitation in the ED (as these patients' care involved clinically mandated and unavoidable time delays). Data was also collected and analysed for STEMI patients presenting to our unit from October 2010 to December 2010 (prior to initiation of the PEP), who served as a control group.

Paramedics educational programme

The local PEP initially held every 4 months between 2011 and 2013 entailed a series of 1-day courses for ambulance personnel directly involved in prehospital management of STEMI patients. Attendees were predominantly from South Central (SCAS) and South-East Coast (SECAMB) ambulance services and included students, technicians and fully trained paramedics, with approximately 50–60 attendees per session. Interventional Cardiologists delivered teaching on all aspects of STEMI care through interactive lectures with emphasis on understanding the importance of STEMI recognition and rapid conveyance to a PPCI-capable centre. Sessions included pathophysiology of STEMI, the evidence and rationale for undertaking PPCI and the crucial importance of timely reperfusion, alongside interactive ECG training workshops, which incorporated recognition and management of both STEMI and its associated ischaemic complications.

The purpose of these sessions was twofold. First, to reinforce the importance of timely detection, triage and direct Cath Lab transfer of STEMI patients, encouraging paramedics to ensure unnecessary contact with the ED was avoided. Second, to empower pre-hospital personnel to initiate early contact with the interventional team, strengthening the link between pre-hospital and specialist care to optimise use of the PPCI pathway. Feedback received from attendees has been highly positive, with a reported increase in confidence to accurately interpret ECG features of STEMI and in management of ischaemic complications.

Data collection and analysis

CTB and DTB data were collected prospectively from ambulance charts, ED data, in-patient clinical notes and discharge summaries, BCIS database, and our department's data for MINAP. All breaches in DTB or CTB targets were investigated to establish the root cause of system delays and identify where and how processes could be improved.

Standard definitions for CTB and DTB times are shown in table 1. Balloon time was documented as time of reperfusion achieved by first medical device (angioplasty wire, aspiration thrombectomy catheter or balloon inflation). Monday to Friday 08:00-18:00 hours was defined as 'in-hours' and all other times including public holidays as 'out of hours.'

SPSS V.21 was used for data analysis. Mann-Whitney U test was used to compare differences in continuous variables (that did not satisfy the assumptions of normality) between groups where a two-tailed probability of $p<0.05$ was defined as significant. For comparison of DTB times in the 'ED' and 'direct' groups, non-parametric Wilcoxon signed rank test was used, where a two-tailed probability of $p<0.05$ was defined as significant.

Patient and public involvement

There was no patient or public input regarding the design, conduct, reporting or dissemination of this study.

RESULTS

Between February 2011 and February 2014, 1028 patients with STEMI were admitted to our unit for emergency

Table 1 Study definition of time measures/intervals	
Time measure/interval	**Definition**
Symptom-onset time	Symptom-onset time reported by patients and/or recorded on ambulance chart
Call for help time	Time of call by patient recorded on ambulance chart
Door time	Arrival time at PCI centre (ambulance +cath lab chart)
Balloon time	Reperfusion time in infarct-related artery achieved by first medical device
Door to balloon	Time interval from documented hospital arrival to documented reperfusion time

PCI, percutaneous coronary intervention.

coronary angiography. Of these 47% (n=484) were transferred by paramedic crews directly from the community for PPCI and 24% (n=244) via the ED giving a study cohort of 728 patients. The remaining 29% (n=300) were excluded due to interhospital transfer, self-presentation, out of hospital cardiac arrest (OOHC), in-hospital cardiac arrest or an initially non-diagnostic ECG with subsequent evolving STEMI.

Patient demographics of the main study cohort (n=728), including coronary risk factor profiles and culprit vessel distribution are shown in table 2. There was a male preponderance (73%, n=531) with risk factors such as hypertension, hypercholesterolaemia and a current or previous smoking history equally represented. Cardiogenic shock was present in 7% (n=51), in keeping with MINAP figures.

Of the total 728 patients, 14.6% (n=106) breached the target DTB of <90 min. The majority of these patients (88%, n=93) had initially been admitted via ED with subsequent transfer to the Cath Lab for PPCI. In contrast, only 1.7% (n=8) of the 484 patients directly admitted to the Cath Lab breached the DTB time target. Between 2011 and 2014, as a result of the regular PEP, we observed a significant and progressive improvement in the appropriate use of the PPCI pathway, with a downward trend in the proportion of STEMI patients admitted via the ED and a concomitant increase in direct cath lab admissions from the community (figure 1).

Head-to-head comparison of DTB and CTB times in those admitted directly or via ED demonstrated significant differences (figure 2). Median DTB times of 37 min (IQR 30–46 min) vs 83 min (IQR, 67–113 min) were seen in the direct versus ED cohorts, respectively (p<0.001). Furthermore, median CTB times of 98 min (IQR, 83–112 min) and 144 min (IQR, 110–158 min) were observed in direct versus ED cohorts (p<0.001). Results consistently demonstrate that any patient contact with the ED led to a statistically significant prolongation of both CTB and DTB times, in agreement with findings from previously published studies.[19 23]

Data was also collected and analysed for 42 STEMI patients presenting to our unit from October 2010 to December 2010 (prior to initiation of the PEP), who met the inclusion/exclusion criteria, as a control group. In this control cohort, 52% (n=22) had direct Cath Lab transfer while 48% (n=20) were admitted via the ED. Median DTB and CTB times were 47 min (IQR 38–60 min) and 91 min

Table 2 Patient characteristics	
Baseline demographic andprocedural characteristic	**No of patients (% of cohort)**
Male	531 (73)
Median age (years)	74 (range 31–96 years)
Hypertension	444 (61)
Diabetes	153 (21)
Hypercholesterolaemia	422 (58)
Current/previous smoking	459 (63)
Previous myocardial infarction	138 (19)
Previous PCI	80 (11)
Previous CABG	29 (4)
Presence of cardiogenic shock	51 (7)
Culprit coronary vessel	
Left anterior descending artery	335 (46)
Right coronary artery	298 (41)
Left circumflex/ramus artery	95 (13)
Final TIMI flow 2/3	721 (99)

CABG, Coronary Artery Bypass Graft Surgery; PCI, percutaneous coronary intervention; TIMI, Thrombolysis in Myocardial Infarction.

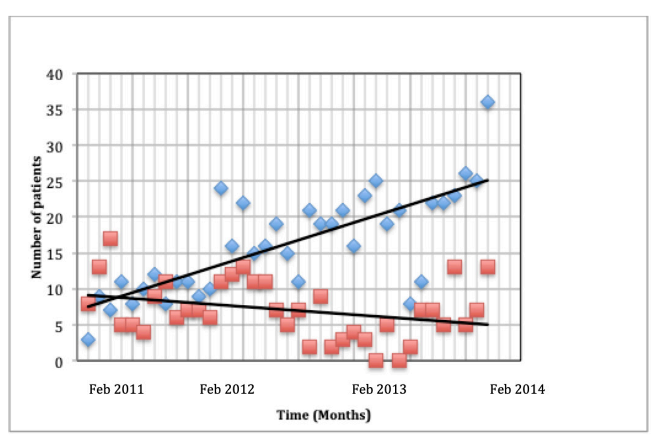

Figure 1 Scatterplot of trend in direct cath lab (blue) versus ED (red) transfer. ED, emergency department.

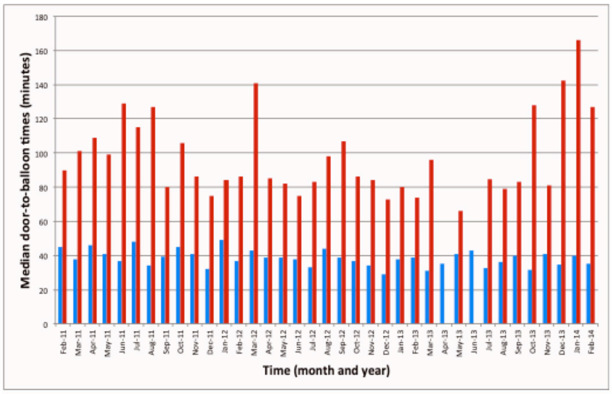

Figure 2 Median door-to-balloon times, direct (blue) versus via ED (red). ED, emergency department.

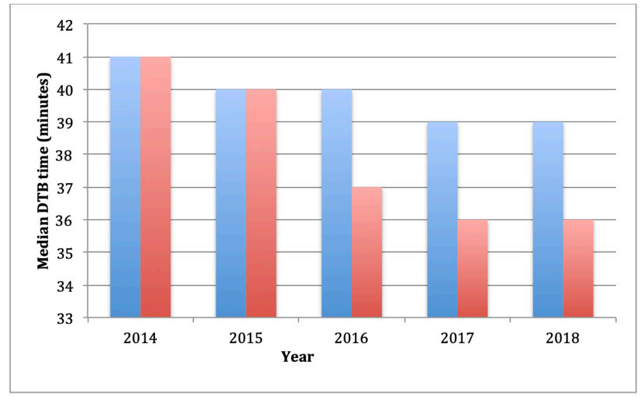

Figure 4 National (blue bars) and local (red bars) median DTB times from 2014 to 2018, demonstrating sustained reduction in DTB times locally, following the PEP. DTB, door-to-balloon; PEP, paramedic education programme.

(IQR 83.5–118 min), respectively, in the direct cohort and 76 min (IQR 67–87 min) and 125 min (IQR 116–143 min), respectively, in the cohort arriving via ED. Direct comparison of DTB and CTB times between this control group and our main study group demonstrated a statistically significant reduction in median DTB time ($p<0.001$) when patients were directly transferred to the Cath Lab, but no significant difference when patient transfer was via ED ($p=0.176$). Furthermore, there were no significant differences in CTB times between control and intervention cohorts following PEP implementation.

Imperative to assessing the success of any intervention such as our PEP, is the ability to demonstrate longer-term sustainability of results. Analysis of DTB times over the 4-year period following initial data collection (2014 to 2018), revealed that continuing paramedic education achieved not only a consistent reduction in DTB times, despite increasing demand on the PPCI service, but also a sustained improvement in the percentage of patients brought directly to the Cath Lab. Analysis of the proportion of patients transferred directly to the Cath Lab during the control, the early PEP (2011–2013) and the established PEP (2014–2018) time periods demonstrated a 63% increase in direct patient transfers to the Cath Lab from 52% (2010) to 85% (2018) (figure 3), reflective of improved use of the PPCI pathway. In the established PEP group, 91% of the cohort achieved a median DTB <90 min and 75% a median DTB <60 min as averaged over the 4-year period. During this time, we have also seen consistent sequential annual improvement in our DTB figures, with a reduction from a median DTB of 41 min in 2014 to 36 min in 2018, surpassing overall national improvements. Figure 4 shows a clear trend in reducing median DTB times following implementation of our local education programme sustained to 2017–2018, where a plateau is reached at 36 min.

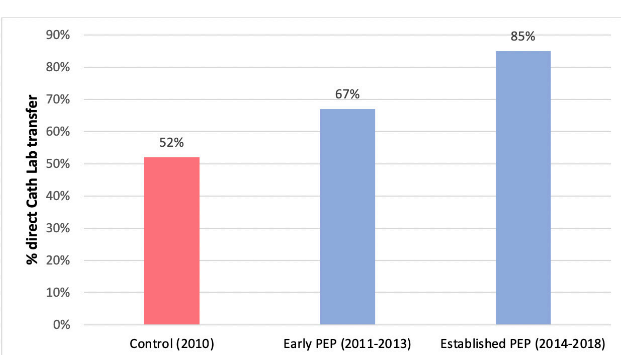

Figure 3 Percentage of patients directly transferred to the cath lab prior to (control) and during the PEP (early and established). PEP, paramedic education programme.

DISCUSSION

Our study finds a demonstrable effect of a specialised education programme for ambulance personnel on local DTB times improving rapidity of reperfusion in a STEMI patient cohort. This was primarily driven by an increase in the proportion of patients admitted directly from the community to the Cath Lab, by-passing the ED. We cannot assume direct causality - several confounders exist which could not be adjusted for within the scope of this study. Potential changes in core paramedic training (external to our PEP), geographical and transport infrastructure and regional ambulance resourcing are thus unaccounted for. However, our overall DTB times improved despite the increased strain on the National Health Servive (NHS), as evidenced by an approximately 37% increase in the volume of calls made to NHS ambulanc services and a 17% rise in ED attendances nationally, without an equivalent increase in funding or resourcing of these services over the time period studied. Hence, we argue that the differences seen in our study are likely predominantly attributable to the PEP.

A greater understanding of the mortality and morbidity benefits of rapid transfer and timely reperfusion encourages prehospital personnel to act swiftly, by-pass ED and more comprehensively manage ischaemic complications aiming to prevent cardiac arrest en route and facilitating safe delivery of STEMI patients to the Cath Lab. The education days served to strengthen links between local paramedics and interventional cardiologists, eliminated hierarchical prejudices and encouraged early conversation with the interventional team in all suspected STEMI cases. This was particularly important where significant electrical or haemodynamic instability existed or when the diagnosis of STEMI was not clear-cut but strongly suspected.

Recognising the challenges of diagnostic and transfer delays in our ED, significant efforts have been made to improve transit times. Monthly multidisciplinary meetings are held, involving senior ED clinicians and ED and prehospital frontline personnel where all DTB/CTB breaches are discussed. Meeting outcomes and planned actions were continually incorporated into the PEP training days, where actual cases of breaches including the scenarios, ECGs and subsequent coronary angiogram findings were presented and key learning points identified, aiming to minimise recurrence. We note that globally, other strategies, including a 'CODE-STEMI' alert protocol have been trialled and demonstrated to improve DTB times through prioritisation and streamlining of ED to Cath Lab pathways. These are innovative and reproducible though success will be dependent on the structure and capacity of individual healthcare systems and their methods of resourcing and service delivery.[24–26]

In our centre, despite the enhanced education of and understanding by the ED clinicians of the time-critical nature of STEMI management, logistical complexities including a saturated department leading to delays in ambulance off-loading, patient triaging and time to first ECG, have made it challenging to facilitate such improvements. Although we are committed to developing and trialling other such strategies to expedite ED transit locally, we propose that at present, the most effective way to deliver optimal patient care in STEMI is through by-passing the ED.[23]

Evidence suggests that unstable patients gain the greatest incremental benefit from rapid reperfusion.[23] This cohort is most likely to be redirected to the ED by paramedic crews, suffering the greatest time delay to an 'open artery'. Education days reinforced the importance of direct Cath Lab transfer, particularly for more unstable patients, reiterating that ischaemic complications of STEMI are most effectively resolved through timely restoration of coronary perfusion. On prealert, when the requirement for extra support is anticipated, emergency crash team members are directly activated to attend the Cath Lab on patient arrival. Our study numbers also reflect this cohort, with 7% of patients directly transferred in clinically defined CS (n=51).

As in all primary PCI services, in our region, there is a 10%–15% rate of false activation of the Cath Lab, both due to cardiac (eg, SCAD, Takotsubo cardiomyopathy, myopericarditis) and less frequently, non-cardiac diagnoses. In this study, we did not collect data to specifically evaluate the impact of our PEP on the rate of false activations of the primary PCI service. We do, however, strongly regard any such 'false activations' of the service as part and parcel of providing a primary PCI service and believe this to be a very important and positive step in the management of such patients, prompting an early review of the patient by a senior cardiologist and when indicated, emergency coronary angiography, which in many cases expedites arriving at the correct diagnosis and facilitates more timely, safe and appropriate management. We certainly do not feel that there are any negative impacts associated with initial emergency assessment of these patients by a senior cardiologist in the Cath Lab environment.

Given the evidence base demonstrating improved patient outcomes with earlier reperfusion,[27–31] minimising system delays and increasing PPCI pathway efficiency is critical. In secondary care, this is most readily achievable through reduction in DTB times. However, despite improvements in DTB times, MINAP data demonstrate increasing median CTB times.[22] This is primarily driven by increasing call-to-door (CTD) time, in turn dependent on the speed of ambulance response, time to first ECG diagnosis of STEMI, ease of patient extraction and repatriation and uncontrollable factors such as local geography and transport infrastructure.

An important consideration is the recent amendment of ambulance response categories within NHS England's Ambulance Response Programme (ARP).[32] Downcategorisation of cardiac chest pain from 'red 2' to 'category 2' has resulted in a longer permitted target response time from a mean of 8 min to 18 min with corresponding 90th percentile target times of 19–40 min. Clearly, this may have a direct impact on national and regional CTB times and highlights the potential for regional healthcare inequalities.

Although increasing CTB times were observed prior to the implementation of these revised ARP parameters, it would seem reasonable to propose that the downcategorisation of cardiac chest pain may have been a contributor to the ongoing rise in CTD and therefore CTB times. This is particularly pertinent given the data demonstrating that every 30 min increase in CTB time increases the hazard of 30-day mortality by 20% for STEMI patients in the UK.[33] Hence, although the new system has enabled more efficient care for patients with cardiac or respiratory arrest, it may have potentially led to an unforeseen trade-off in the immediate and emergency care of STEMI patients. Optimisation of the PPCI pathway is of even greater topical relevance given the detrimental effects of the COVID-19 pandemic on STEMI care and clinical outcomes both in the UK and globally.[34–36]

Limitations

There are a number of limitations to our study. First, it represents a single PPCI centre's experience over a fixed time period and although our intervention (PEP) is readily reproducible, our methods and results may not be universally applicable. For example, our centre benefits from out of hours dedicated cardiology middle grade doctors and senior CCU nurse cover - this allows us to accept STEMI patients directly to the Cath Lab prior to the arrival of the PPCI team. In smaller centres, the ED maybe a holding place of safety for STEMI patients until the on-call team have arrived. Second, we cannot assume causality between our PEP and the observed improvement in DTB times, as confounders including external changes to paramedic training or self-based study, resource availability and geographical determinants cannot be accounted for. Third, although we did not observe significant differences in CTB times, our study could not directly or exclusively assess the effects of the PEP on CTD times. However, based on the MINAP data, this is the component of the STEMI pathway that continues to deteriorate. We propose that the undertaking of multicentre studies assessing the impact of individual interventions on CTB time should be a key area of focus in the future aiming at further reduction of STEMI pathway delays.

CONCLUSION

It is imperative to remain committed to ongoing improvement of STEMI care and mortality reduction, particularly in the advent of increasing patient fragility, resource limitation and economic strain within the NHS. Our study is the first to demonstrate a significant reduction in DTB times with regular implementation of a local PEP. This was primarily driven by appropriate use of the PPCI pathway with a 63% increase in direct Cath Lab transfer. Sustainability of our intervention was observed through to 7 years post-implementation, emphasising the importance of continual training on maintaining high standards of care. Our PEP represents a simple and effective way of achieving this goal with reproducibility to other PPCI networks nationally. However, we acknowledge that ongoing efforts to improve DTB times will likely be offset by the trend in rising CTD times. Future research and logistical and resource optimisation of the PPCI pathway is required to ensure standardisation of guideline-directed optimal and equitable care for all STEMI patients across the UK.

Twitter Kalaivani Mahadevan @KVM83

Contributors KM: data acquisition, analysis and interpretation, manuscript drafting and critical revision. DS: data acquisition, analysis and interpretation, manuscript drafting and critical revision. CW: data acquisition, PEP implementation and manuscript critical revision. AM: data acquisition and analysis. AH: PEP implementation and manuscript critical revision. PS: PEP implementation and manuscript critical revision. HG: PEP implementation and manuscript critical revision. AD: research conception and design, PEP implementation, data analysis, interpretation and manuscript critical revision. All authors have contributed to the revision of the manuscript and have accepted the final version. Guarantor: AD accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Ethics approval was not required as this study was undertaken as part of a service evaluation project and all included data was both anonymised and already routinely collected for national audit purposes.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. Limited patient-level data across all MINAP mandated categories, stored within the local hospital database, can be made available on reasonable request.

ORCID iD

Kalaivani Mahadevan http://orcid.org/0000-0002-9414-6945

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