

# Advances in the treatment of ST Elevation Myocardial Infarction in the UK

JRSM Cardiovascular Disease

Volume 11: 1–10

© The Author(s) 2022

Article reuse guidelines:

sagepub.com/journals-permissions

DOI: 10.1177/20480040221075519

journals.sagepub.com/home/cvd



Lal Hussain Mughal<sup>1</sup>  and Sanjay Sastry<sup>2</sup>

## Abstract

The treatment of acute coronary occlusion with Primary PCI has been a major factor in improving outcomes of patients suffering STEMI in the last 15 years, and is the standard treatment for patients suffering STEMI in the UK.

Treatment is beneficial for patients presenting within 12 hours of the onset of symptoms, with the goal being opening of the occluded artery within 150 min of the call for help.

Opening of the occluded artery is typically completed with a drug-eluting stent followed by administration of antiplatelet medications for 12 months. Procedures are performed using the radial artery which is associated with improved outcomes compared to vascular access via the femoral artery.

Evidence is growing to support full revascularisation including the treatment of severe narrowing in other blood vessels as well as the culprit vessel.

## Keywords

STEMI, acute coronary occlusion, primary percutaneous coronary intervention, balloons and stents

Date received: 26 February 2021; Revised 13 December 2021; accepted: 4 January 2022

There have been considerable developments in the last 15 years in the treatment of patients with ST-segment elevation myocardial infarction (STEMI), including the widespread application of emergency primary percutaneous coronary intervention (PPCI). In this article, we are going to describe STEMI, its pathophysiology and advances in its management.

## Diagnosis of STEMI

Criteria for the diagnosis of STEMI are:

- Presentation with clinical symptoms consistent with an acute coronary syndrome (typically acute onset of chest pain) together with S-T segment elevation on ECG.
- ECG changes of Left Bundle Branch (LBBB) with additional criteria suggesting STEMI (Sgarbossa criteria) and Posterior STEMI may be included in this sub-heading as the treatment approach is similar; however, this needs to be correlated with patient symptoms.<sup>1,2</sup> Recent ESC guidelines have also included other ECG criteria for consideration of urgent angiography.<sup>3</sup>

## Pathophysiology:

An ST elevation myocardial infarction (STEMI) most commonly occurs when plaque rupture and thrombus formation results in complete occlusion of a major epicardial coronary

vessel. STEMI is a life-threatening, time-sensitive emergency that must be diagnosed and treated promptly. This is because heart muscle starts to be lost once a coronary artery is occluded, and the sooner reperfusion therapy is delivered, the better the outcome for the patient. Nearly half of potentially salvageable myocardium may be permanently damaged within 1 hours (h) of the coronary artery being occluded, and two-thirds within 3 h.<sup>4</sup> The extent of myocardial damage may be affected by the presence of any collateral supply to the ischaemic territory from other coronary arteries.

## History of emergency coronary reperfusion therapy:

Complete coronary occlusion causing STEMI was demonstrated more than 35 years ago using coronary angiography.<sup>5</sup> This resulted in clinical trials of 'clot-busting'

<sup>1</sup>Senior Clinical Fellow in Interventional Cardiology, Wythenshawe Hospital, Manchester University Foundation Trust, UK

<sup>2</sup>Consultant Interventional Cardiologist, Wythenshawe Hospital, Manchester University Foundation Trust, UK

## Corresponding author:

Lal Hussain Mughal, Locum Consultant Interventional Cardiologist  
Worcestershire Royal Hospitals NHS Trust, UK; Senior Clinical Fellow in  
Interventional Cardiology, Wythenshawe Hospital, Manchester University  
Foundation Trust, UK.

Email: mughal\_doc@yahoo.co.uk



(thrombolytic, fibrinolytic) and other drugs being undertaken to reopen the affected coronary arteries, and thereby limit myocardial damage.<sup>6</sup>

During the 1980s and 1990s, the optimal means of achieving restoration of flow was to administer a fibrinolytic drug. The UK introduced a comprehensive system for delivering fibrinolysis following the publication of the National Service Framework (NSF) for Coronary Heart Disease in 2000.<sup>7</sup> However, whilst shown to be much more effective than placebo, fibrinolysis was not without its limitations. Around 30% of cases were unsuitable for fibrinolysis (e.g. because of high bleeding risk): failure of coronary reperfusion occurred in around 20% - 30%: and in a few (1.0%) it caused a haemorrhagic stroke. Even if the vessel was successfully reopened, the rate of re-occlusion, causing a further MI, was high.

### *Rationale behind primary percutaneous intervention (PPCI):*

The above deficiencies in thrombolytic treatment led to attempts to improve outcomes through mechanical techniques as a means of restoring coronary flow (coronary angioplasty, thrombus extraction catheters, stenting), that are grouped under the overarching term 'primary percutaneous coronary intervention' (PPCI).

The use of percutaneous coronary angioplasty to treat narrowing and blockages in epicardial vessels dates back to the late 1970s. The first angioplasty was performed by Dr A Gruentziq in Sept 1977 on a patient with a left anterior descending artery (LAD) stenosis. Nine years later, Puel implanted the first (self-expanding) coronary stent and one year later, in 1987, Palmaz and Schatz presented the first balloon-expandable stent. Over the subsequent 33 years, stent technology has developed rapidly enabling the use of primary percutaneous intervention (PPCI) in the way we know it today.

### *Primary percutaneous coronary intervention VS thrombolysis:*

Percutaneous coronary intervention (PCI) had been used by individual centres for the treatment of acute ST-elevation myocardial infarction (STEMI) for many years, but it was not until the DANAMI-2 and PRAGUE-2 trials, and the ensuing meta-analysis by Keeley et al. that PPCI became more widely acknowledged as the preferred method of reperfusion. These studies showed both a reduction in short term mortality (7% vs 9%, P 0.0002) and a combined endpoint of death, stroke and re-infarction (8% vs 14%, P 0.0003).<sup>8-10</sup> While the evidence from these trials had demonstrated the superiority of PPCI over fibrinolysis, implementation in the UK at that time required major infrastructural and organisational changes, and an assessment of the cost-effectiveness and sustainability of a 24/7 PPCI reperfusion strategy assessment was needed.

## **PPCI guidelines and best practice**

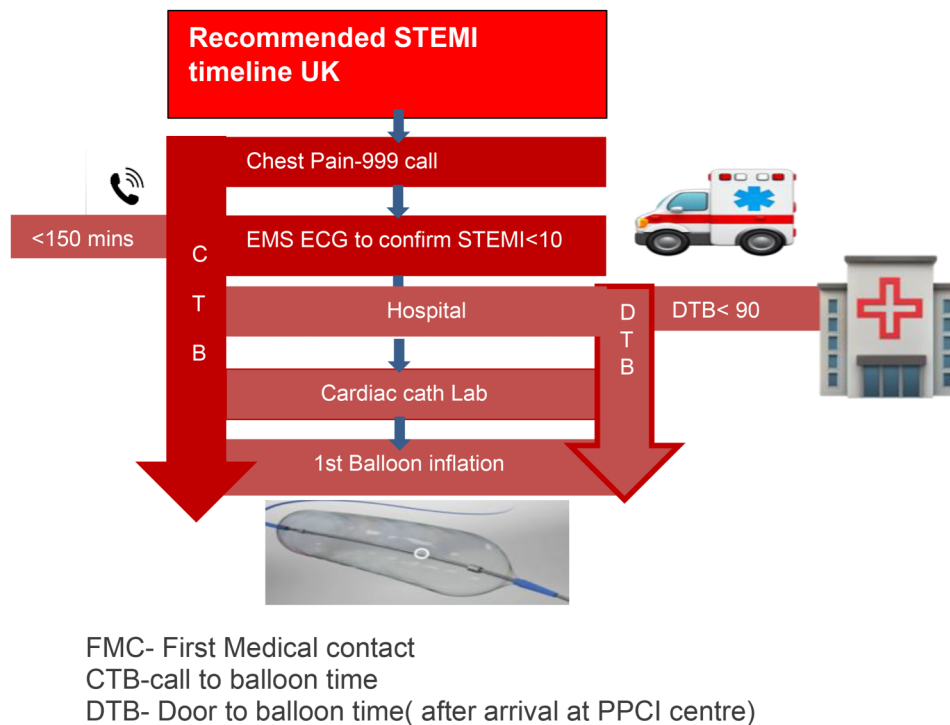
Like thrombolysis, studies had clearly shown that the effectiveness of PPCI as a reperfusion therapy is time-dependent.<sup>10</sup> Reflecting this evidence, the European Society of Cardiology and European Association of Cardiothoracic Surgery (ESC/EACTS) 2018 Acute Coronary Syndrome (ACS) guidelines give a class I recommendations with level of evidence A indication for treatment of STEMI patients with PPCI within 12 h, a I level of evidence C recommendation for PPCI beyond 12 h and Ila level of evidence B recommendation for a routine primary PCI strategy in patients presenting late (12–48 h) after the onset of symptoms.<sup>3,11</sup>

As well as time from onset of symptoms, multiple studies have shown the importance of minimising the delay from the call for help to the opening of the occluded artery. **The call to balloon time (CTB)** is an expression of the overall response of the healthcare system.<sup>12</sup> The UK NICE quality measure suggests that a call-to-balloon time of up to 150 min is acceptable<sup>13</sup>. A position paper of the British Cardiovascular Intervention Society (BCIS) endorsed an audit standard of a call-to-balloon time of less than 150 min in at least 75% of patients (excluding those presenting with cardiogenic shock or needing ventilation before the procedure).

**Door-to-balloon time (DTB)** is the interval between the time of ambulance arrival outside the PPCI hospital and the time to balloon inflation to open the occluded artery. This is an expression of the 'PPCI hospital response'. A DTB time of less than 90 min has been the standard for hospital response to higher-risk heart attacks. However, a British Cardiovascular Intervention Society (BCIS) position paper suggested that optimal performance should be defined as a door-to-balloon time of less than 60 min in at least 75% of patients (excluding those presenting with cardiogenic shock or needing ventilation before the procedure). The current recommendation from ESC remains at <90 min in all eligible cases which reflects the data on mortality benefit from published studies.<sup>14</sup> The patient pathway including CTB and DTB is illustrated in Figure 1.

### *Implementation and assessment of effectiveness and feasibility of primary percutaneous coronary intervention (PPCI) in the UK:*

To investigate the potential for PPCI to be delivered in England, from April 2005 to March 2006 the Department of Health undertook a feasibility study (National Infarct Angioplasty Project - NIAP). This was an observational study set up in collaboration with the British Cardiovascular Society (BCS) and BCIS to test the feasibility of developing angioplasty services as the initial treatment for STEMI across England. This study reported in 2008 and concluded that PPCI is both feasible and cost-



**Figure 1.** Flow chart showing STEMI timeline. FMC- First Medical contact. CTB-call to balloon time. DTB- Door to balloon time(after arrival at PPCI centre).

effective and that it should become the treatment of choice for STEMI, provided it could be delivered in a timely fashion.<sup>15</sup> Central to this PPCI strategy is emergency access to specialist cardiac catheter laboratories and staff.

The issue of ‘timeliness’ formed a key part of this guideline. As a part of NIAP, an analysis of expected ambulance travel times was undertaken and estimated that approximately 95% of the population lived close enough to a PPCI centre for this to be their routine reperfusion treatment and that therefore around 5% might still require fibrinolysis.

### Current UK PPCI services and performance

There has been a substantial improvement in PPCI services across the UK over the last two decades. During the third quarter of 2008, only 46% of those STEMI patients in the UK who received reperfusion treatment were being treated by PPCI, while the remaining 54% were treated with thrombolysis. Following the publication of the NIAP report in August 2008, there was a coordinated rollout of PPCI services in England. The use of primary angioplasty continued to increase between 2008 and 2011. By the second quarter of 2011, 94% of STEMI patients in England were being treated with PPCI. By 2017/18, 58 out of 98 NHS PCI hospitals/centres offered primary PCI for the emergency treatment of STEMI, 24/7 every day of the year, and a further ten linked to form hybrid services.

The changes to treatment of STEMI treatment over time are illustrated in Table 1.

As described in the 2019 NICOR report; in the last 5 years, DTB times (hospital performance) have remained the same, but there has been a lengthening of CTB times implying that ambulance response times have become slower. The reasons for this deterioration in the pre-hospital phase are unclear and are being investigated at national level, but are likely to reflect the increasing pressures on the system as a whole and the ambulance service in particular

### Key aspects of optimal STEMI treatment by PPCI:

Primary PCI has been the focus of many research studies in the last 20 years, resulting in improvements in all aspects of care as summarised below;

**A. Institutional standards.** Although PCI has been used as a mainstay of STEMI treatment for many years, BCIS published a formal standards/guidance document for PCI and PPCI in 2015:

#### A1. Institutional facilities

- Two cardiac dedicated catheter laboratories are the minimum requirement for a PCI service undertaking emergency cases.

**Table 1.** Changes to PPCI practice 2008-2018/19 based on yearly BCIS audits.

Treatment/Devices	2008	2018–2019
<b>Thrombolysis</b>	80% of cases	Rarely used
<b>Primary PCI procedures</b>	<b>12% of cases</b>	<b>&gt;90% of cases</b>
<b>Call to balloon time(&lt;150 min)</b>	116(79%)	126(69%)
<b>Door to balloon time(&lt;90 min)</b>	<b>54(81%)</b>	<b>40(89%)</b>
<b>Drug eluting stents</b>	32%	90%
<b>Radial access</b>	<b>32%</b>	<b>87%</b>
<b>Mortality</b>	4.1%	5.4%

- Digital Imaging and Communications in Medicine archiving of images.
- Physiological assessment facilities are needed in all interventional laboratories.
- Radiation protection monitoring is mandatory

#### A2. Institutional volume

- Minimum centre volume is 400 cases/year.
- Minimum of three interventional cardiologists per centre.
- PPCI centres should have at least two catheter laboratories and 24/7 provision of service for STEMI.
- PPCI centres should perform an absolute minimum of 100 STEMI/PPCI cases/year<sup>16</sup>

#### A3. Surgical cover

- The AHA/ACC 2011 guidelines include a Class IIa recommendation for PPCI in hospitals without on-site surgery
- In the UK the number and proportion of centres performing PCI without on-site surgery continue to increase year-on-year, and is now in the majority. About 40% of total UK PPCI cases are performed in non-surgical centres. Reassuringly two major trials Cardiovascular Patient Outcomes Research Team Trial (CPORT-E) and Massachusetts Hospitals with Cardiac Surgery On-Site and Community Hospitals without Cardiac Surgery On-Site (MASS COMM) published in 2012 and 2013 respectively showed no difference in safety and mortality between surgical and non-surgical sites.<sup>17,18</sup>

**B. Patient preparation:** Wherever possible, patients undergoing PPCI need to be appropriately consented for the procedure. In some UK centres this is a verbal consent process, due to concerns about the validity of asking patients to sign standard consent forms whilst suffering an MI and after

receiving opiate analgesia. This approach was validated as part of the HEAT study.<sup>19</sup> Patients need to be loaded with dual antiplatelet therapy as per STEMI guidelines. Patients who are unable to take oral medications (unwell, intubated ventilated or those with severe bystander CAD requiring urgent coronary bypass grafting) may need a period of bridging with an intravenous antiplatelet such as cangrelor or glycoprotein 2B3A inhibitors.

**C. Vascular Access:** Accessing the heart from the upper limb is not new, having been originally done in 1929 by Dr Werner Forssmann who performed the first human cardiac catheterisation via a brachial vein. Dr Frank Mason Sones performed the first coronary catheterization through the brachial artery by the arterial cut-down technique in 1958. In 1989, 100 trans-radial angiography cases were reported by Lucien Campeau and the first radial intervention was done by Kiemeneij and Laarman in 1993.<sup>20</sup>

In the early days of angiography and angioplasty, femoral artery access was the preferred vascular access. However, more recently the radial artery access has become the default procedural access route. The clinical advantages of the radial over femoral are mainly due to less access site bleeding. As the radial artery is small, superficial and easily compressible, bleeding complications associated with radial arterial access are rare. Its safety has been established in both STEMI<sup>21,22</sup> as well as ACS.<sup>23,24</sup> In STEMI patients there is also clear evidence of improved outcomes from the use of radial compared to femoral access.<sup>25</sup> In selective cases such as weak or absent radial pulses (following usage as a graft), tortuous radial or subclavian anatomy, or cardiogenic shock, femoral access may be used as an alternative. The availability of ultrasound-guided access has reduced femoral related bleeding events and increased first-pass success<sup>26</sup> which may be helpful in cases like cardiogenic shock, where additional large-bore access may be required to insert mechanical support such as an Intra-aortic balloon pump (IABP) or Impella depending on availability in the centre.

According to current BCIS data, radial artery access has increased from just over 10% in 2004 to 87.2% in 2017–2018 for all cases and almost 86% of PPCI cases are performed through radial access. The current ESC and American guidelines have an IA recommendation for radial access in PPCI.

**D. Choice of balloon or stent treatment in PPCI.** Following vascular access, the Right or Left Infarct Related Artery (IRA) is intubated with respective guide catheters, the occlusion is crossed with a guidewire, pre-dilated with an angioplasty balloon and treated with the appropriate size (length and diameter) stent or drug-coated balloon.

There have been dramatic improvements in balloon and stent technology since angioplasty was started. The initial era of balloon angioplasty or POBA (1970–1980) was

later replaced by the implantation of bare metal stents (BMS) (1980–1999), and finally by drug-eluting stents (1999 onwards) and drug-coated balloons (DCB). Geoffrey Hartzler in 1979 used the first balloon angioplasty and Cannon and Roubin in 1991 used the first stent to treat AMI. The downsides of POBA were acute vessel closure due to dissection or elastic recoil, and restenosis of coronary arteries from late vascular remodelling and neo-intimal proliferation. Elastic recoil occurred within minutes to hours in 5–10% of POBA cases and often led to severe complications, including acute myocardial infarction (AMI) and the need for emergency coronary artery bypass grafting (CABG). This led to the development of metal scaffolds to reduce the risk of vessel recoil and restenosis. Initial self-expandable, and later FDA approved balloon-expandable bare-metal stents, were developed in the late 1980s and early 1990s. In 1993, two landmark trials, the Belgium Netherlands Stent Arterial Revascularization Therapies Study (BENESTENT)<sup>27</sup> and the North American Stent Restenosis Study (STRESS)<sup>28</sup> demonstrated the superiority of the bare-metal stents (BMS) over POBA. This established coronary stent implantation as an accepted standard of care for PCI and the FDA approved the use of stents to treat AMI (STEMI and NSTEMI) after failed balloon angioplasty. The use of coronary stents increased exponentially over the next few years and by 1999, stents were used in nearly 85% of PCI procedures. However, the medium and longer-term follow-up of BMS revealed in-stent restenosis (ISR) in 20–30% of cases, due to proliferation and migration of vascular smooth muscle cells (VSMCs) within the stents. ISR may be associated with significant morbidity and mortality, and drug-eluting stents (DES) were developed specifically to address the problems of ISR encountered with BMS.<sup>29</sup> Dr Eduardo Sousa in 1999 performed angioplasty using the first drug (sirolimus) eluting stent in a human coronary artery, and between 2002 and 2004 Cypher and Taxus stents were approved for use across Europe and the USA.<sup>30–32</sup> From early 2000 onwards, the use of DES became the standard of care in all contemporary PCI procedures, with BMS reserved for high bleeding risk patients, or patients requiring short duration antiplatelet treatment for any other reason eg undergoing any urgent major surgical procedure. Since the development of new generation stents (including polymer-free stents) and drug-coated balloons, BMS are rarely used in the UK now.<sup>33,34</sup> POBA may still be used in selected PPCI cases with severe bystander coronary disease to restore flow to the infarct artery as a bridge to emergency CABG. Given the success of DES, angioplasty balloons coated with drugs/drug-eluting balloons (DCB/DEB), have also been developed to treat small <2.5 mm diameter coronary arteries and any form of in-stent restenosis.<sup>35</sup> DEB-only treatment is also an option during PPCI, such as in patients with contra-indications to drug-eluting stents.<sup>36</sup>

**E. Primary Angioplasty and Antiplatelet/antithrombotic therapy.** Periprocedural use of unfractionated heparin (UFH) is standard in PPCI cases to avoid the development of in situ thrombus in vessels and catheters (class IC recommendation by ESC 2017 STEMI guidelines). The use of Bivalirudin has been compared to UFH, but there was no evidence of benefit, so this medication is reserved for cases of Heparin allergy or Heparin-Induced Thrombocytopenia.<sup>37</sup>

Dual antiplatelet therapy (DAPT) is recommended for 12 months after PPCI irrespective of stent type, while in patients at high ischaemic risk with low bleeding risk, DAPT may be extended beyond 12 months.<sup>38</sup> If dual antiplatelet therapy (DAPT) cannot be sustained beyond 1-month post-intervention, treatment with short-duration DAPT stents or other modalities such as POBA, DEB may be considered.<sup>39</sup> DAPT regimens tested in clinical trials for PPCI include Aspirin with Clopidogrel, Prasugrel and Ticagrelor. Recent NICE guidance has recommended Prasugrel as the agent of first choice predominantly on the basis of safety and efficacy data and ease of use as a once daily drug.<sup>40–42</sup>

Some STEMI patients will have an additional indication for anticoagulation (usually Atrial Fibrillation). Multiple large RCTs have shown this cohort of patients now can safely be treated with an oral anticoagulant and two antiplatelet agents, followed by a period of anticoagulant with single antiplatelet.<sup>43–47</sup> The current ESC 2020 guidelines recommend between 0–6 months of triple therapy based on individual patient ischaemic and bleeding risk, though durations of triple therapy of less than 3 months are more common in UK practice.

**F - Adjunctive procedures and therapy in PPCI.** In selective STEMI cases with a high thrombus burden, aspiration of thrombus with a catheter may be performed (thrombectomy) to improve coronary flow and reduce the risk of distal embolization. Recommended in the 2008 TAPAS study with 1027 STEMI patients, thrombus aspiration resulted in better reperfusion and clinical outcomes than conventional PCI, irrespective of clinical and angiographic characteristics at baseline.<sup>48</sup> However the TOTAL study (2015) of more than 10,000 patients with STEMI showed that routine thrombectomy, as compared with PCI alone, did not reduce the risk of cardiovascular death, recurrent myocardial infarction, cardiogenic shock, or NYHA class IV heart failure within 180 days but was associated with an increased rate of stroke within 30 days.<sup>49</sup> Current guidelines do not recommend routine use of thrombectomy (III level of evidence A), but it is reserved as a bailout in selective high-risk cases only.

Patients with a heavy thrombus burden are at risk of developing no-reflow in the culprit vessel, potentially due to embolization of clot into the coronary microcirculation, which is associated with poorer outcomes.<sup>50</sup> Whilst some

small scale studies have suggested that additional treatment with agents including intracoronary nitrates, adenosine, calcium channel blocker (verapamil, diltiazem and nicardipine) or sodium nitroprusside could potentially improve flow, there is a paucity of clear randomised evidence in this area.<sup>51</sup>

Those patients with previous bypass grafts presenting with STEMI due to an occluded graft are at high risk of no-reflow or distal embolization. Studies have indicated that an Embolic protection Device could help reduce this risk during PCI.<sup>52-54</sup> ESC guidelines recommend embolic protection as II level of evidence B. In addition, direct stenting and smaller stent size in the graft vessel have been shown to reduce the risk of distal embolization.<sup>55</sup> Adjunctive use of adenosine could also help with no-reflow.<sup>56</sup>

The use of intracoronary imaging has been proven to improve outcomes in elective PCI in a number of studies, but its routine use has not been proven in STEMI to date.<sup>57,58</sup> Intracoronary imaging may be particularly helpful in selected cases to clarify the underlying pathology e.g. Spontaneous Coronary artery dissection (SCAD) or Myocardial Infarction in Non-Obstructive Coronary Arteries (MINOCA).

In STEMI patients presenting with MI complicated by shock, additional mechanical circulatory support may be required. The use of the Intra-Aortic Balloon Pump has been studied and found not to be of significant benefit. Randomised trials supporting the use of LV assist devices such as Impella are awaited.<sup>59-62</sup>

**G. Deferred VS immediate PCI in STEMI patients.** Several observational studies have suggested that deferred stenting (initial opening of the occluded vessel with a balloon followed by stenting after 24–72 h) was associated with higher rates of procedural success, higher 6-month left ventricular ejection fraction (LVEF), and lower rates of adverse events compared with immediate stenting.<sup>63-65</sup> Recently, findings from new randomized controlled trials (RCTs) have shown inconsistent results compared to previous observational studies.<sup>66,67</sup> A comparative meta-analysis showed that a deferred-stenting strategy did not reduce the occurrence of no-reflow or slow flow, death, MI, or repeat revascularization compared with immediate stenting in patients with STEMI, but did show improved LV function in the long term. Following this meta-analysis, the majority of vessels are treated with immediate stenting.<sup>68</sup>

**H. Single versus multivessel(MV) PCI.** Around 30%-40% of patients presenting with STEMI have significant bystander coronary artery disease (CAD). We know that the presence of significant disease in vessels other than the infarct-related artery (IRA) has an adverse prognosis following primary PCI.<sup>69</sup>

Four major RCTs have shown a benefit of complete revascularization (performed immediately or staged) as

compared with Infarct Related Artery (IRA) only PCI in patients with STEMI and multi vessel disease (MVD).<sup>70-74</sup> The Complete Revascularisation with MV PCI for Myocardial infarction (COMPLETE) study was a much larger RCT than those previously undertaken to assess this issue. This study and previous meta-analysis of 10 trials has shown that complete revascularization is associated with a lower risk of major adverse cardiovascular events (MACE), due to a lower risk of urgent revascularization, with no significant difference in mortality.<sup>74,75</sup> These studies support the concept of full revascularization, and this has now been adopted into modern practice.

In terms of optimal timing of complete revascularisation, the COMPLETE study showed no difference in outcomes whether the procedure was performed during the indexed hospital stay for STEMI or a staged admission within 45 days. Further studies are needed to clarify how clinicians can identify which lesions should be revascularized beyond the culprit lesion.

In patients with multi-vessel disease and AMI with cardiogenic shock, the CULPRIT-SHOCK trial showed that a strategy with PCI of the culprit lesion only with possible staged revascularization determined a lower 30 day and one year risk of the composite of all-cause mortality or severe renal failure compared with immediate multi-vessel PCI.<sup>76,77</sup> In the light of Culprit- Shock trial, In the setting of cardiogenic shock, immediate MV PCI is not now recommended by ESC guidelines.

**I. Thrombolysis/Thrombolysis facilitated PCI.** In busy PPCI centres, multiple patients arriving at the same time may affect door-balloon times, and so outcomes for individual patients. In these infrequent situations, thrombolysis facilitated or pharmaco-invasive PCI strategy is a useful alternative. In this strategy, patients with a possible delay in CTB/DTB may receive a half dose of the thrombolytic agent to minimise myocardial damage prior to definitive PCI. Trials have shown this is a safe and effective second-line pathway which can be considered.<sup>78,79</sup>

**J. Primary PCI in patients with out of hospital cardiac arrest (OOHCA):** CAD remains the leading cause of OOHCA. Where there is ST Elevation on the ECG in OOHCA patients, PPCI is the treatment of choice in PPCI centres in the UK. The ESC 2017 guidelines recommend performing immediate/emergent coronary angiography and angioplasty in survivors of OOHCA with ST-segment elevation on the ECG (I level of evidence B). These guidelines also advocate urgent angiography and PCI in patients without ST elevation but on-going ischaemia (IIaC). There are limited data to guide the treatment of OOHCA patients without ST Elevation after the return of spontaneous circulation and no clear ongoing ischaemia. Two recently published studies have not supported early angiography in patients without ST Elevation on their ECG.<sup>80-82</sup>

## Secondary prevention treatment in STEMI patients:

In addition to PPCI and the antiplatelet medications described above, a number of other interventions are recommended in guidelines for STEMI patients. Modern PPCI services also ensure the delivery of these additional investigations, such as echocardiography to assess LV function, and treatments including statins, ACE inhibitors and aldosterone antagonists. A key post-MI therapy is Cardiac rehabilitation, which has some of the greatest benefits to patients of all MI treatments. Clinical trials have shown both physical and psychological benefits with areas of focus including health education, post MI stress management, sexual health, drivig advice and lifestyle changes after an MI.<sup>83</sup>

## Summary

The treatment of acute coronary occlusion with Primary PCI has been a major factor in improving outcomes of patients suffering STEMI in the last 15 years, and is the standard treatment for patients suffering STEMI in the UK.

Treatment is beneficial for patients presenting within 12 h of the onset of symptoms, with the goal being opening of the occluded artery within 150 min of the call for help.

Opening of the occluded artery is typically completed with a drug-eluting stent followed by administration of antiplatelet medications for 12 months. Procedures are performed using the radial artery which is associated with improved outcomes compared to vascular access via the femoral artery.

Evidence is growing to support full revascularisation including the treatment of severe narrowing in other blood vessels as well as the culprit vessel.

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

## ORCID iD

Lal Hussain Mughal  <https://orcid.org/0000-0002-7469-9147>

## References

1. Sgarbossa EB, Pinski SL, Barbagelata A, et al. Electrocardiographic diagnosis of evolving acute myocardial infarction in the presence of left bundle-branch block. GUSTO-1 (Global Utilization of Streptokinase and Tissue Plasminogen Activator for Occluded Coronary Arteries) Investigators.
2. Meyers HP, Limkakeng AT Jr, Jaffa EJ, et al. Validation of the modified sgarbossa criteria for acute coronary occlusion in the

setting of left bundle branch block: a retrospective case-control study. *Am Heart J* 2015; 170: 1255–1264.

3. Ibanez B, James S, Agewall S, et al. 2017 ESC guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: the task force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European society of cardiology (ESC). *Eur Heart J* 2018; 39: 119–177.
4. Reimer KA, Lowe JE, Rasmussen MM, et al. The wavefront phenomenon of ischemic cell death. 1. Myocardial infarct size vs duration of coronary occlusion in dogs. *Circulation* 1977; 56: 786–794.
5. DeWood MA, Spores J, Notske R, et al. Prevalence of total coronary occlusion during the early hours of transmural myocardial infarction. *N Engl J Med* 1980; 303: 897–902.
6. Rentrop KP, Blanke H, Karsch KR, et al. Acute myocardial infarction: intracoronary application of nitroglycerin and streptokinase. *Clin Cardiol* 1979; 2: 354–363.
7. Lloyd-Mostyn R. National service framework for coronary heart disease. *Br Med J* 2000; 321: 634.
8. Andersen HR, Nielsen TT, Rasmussen K, et al. A comparison of coronary angioplasty with fibrinolytic therapy in acute myocardial infarction. *N Engl J Med* 2003; 349: 733–742.
9. Widimský P, Budesínský T, Vorác D, et al. Long distance transport for primary angioplasty vs immediate thrombolysis in acute myocardial infarction. Final results of the randomized national multicentre trial-PRAGUE-2. *Eur Heart J* 2003; 24: 94–104.
10. Keeley EC, Boura JA and Grines CL. Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. *Lancet* 2003; 361: 13–20.
11. Neumann F-J, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS guidelines on myocardial revascularization. *Eur Heart J* 2019; 40: 87–165.
12. Varcoe RW, Clayton TC, Gray HH, on behalf of the British Cardiovascular Intervention Society (BCIS) and the National Institute for Cardiovascular Outcomes Research (NICOR), et al. Impact of call-to-balloon time on 30-day mortality in contemporary practice. *Heart* 2017; 103: 117–124.
13. Surveillance report 2016 – Unstable angina and NSTEMI (2010) NICE guideline CG94 and Myocardial infarction with ST-segment elevation (2013) NICE guideline CG167. London: National Institute for Health and Care Excellence (UK); September 29, 2016.
14. McNamara RL, Wang Y, Herrin J, et al. Effect of door-to-balloon time on mortality in patients with ST-segment elevation myocardial infarction. *J Am Coll Cardiol* 2006; 47: 2180–2186.
15. Green M. How national policy affects the care of patients who suffer a heart attack. *Br J Nurs* 2012; 21: 1199–1203.
16. Banning AP, Baumbach A, Blackman D, et al. Percutaneous coronary intervention in the UK: recommendations for good practice 2015. *Heart* 2015; 101: 1–13.
17. Aversano T, Lemmon CC and Liu L, Atlantic CPORT Investigators. Outcomes of PCI at hospitals with or without on-site cardiac surgery. *N Engl J Med* 2012; 366: 1792–1802.
18. Jacobs AK, Normand S-LT, Massaro JM, et al. Nonemergency PCI at hospitals with or without on-site cardiac surgery. *N Engl J Med* 2013; 368: 1498–1508.



19. Shaw D. HEAT-PPCI sheds light on consent in pragmatic trials. *The Lancet* 2014; 384: 1826–1827.
20. Kiemeneij F, Laarman GJ and de Melker E. Transradial artery coronary angioplasty. *Am Heart J* 1995; 129: 1–7.
21. Bernat I, Horak D, Stasek J, et al. ST-segment elevation myocardial infarction treated by radial or femoral approach in a multicenter randomized clinical trial: the STEMI-RADIAL trial. *J Am Coll Cardiol* 2014; 63: 964–972.
22. Romagnoli E, Biondi-Zoccai G, Sciahbasi A, et al. Radial versus femoral randomized investigation in ST-segment elevation acute coronary syndrome: the RIFLE-STEACS (Radial Versus Femoral Randomized Investigation in ST-Elevation Acute Coronary Syndrome) study. *J Am Coll Cardiol* 2012; 60: 2481–2489.
23. Jolly SS, Yusuf S, Cairns J, et al. Radial versus femoral access for coronary angiography and intervention in patients with acute coronary syndromes (RIVAL): a randomised, parallel group, multicentre trial. *Lancet* 2011; 377: 1409–1420.
24. Valgimigli M, Frigoli E, Leonardi S, et al. Radial versus femoral access and bivalirudin versus unfractionated heparin in invasively managed patients with acute coronary syndrome (MATRIX): final 1-year results of a multicentre, randomised controlled trial. *Lancet* 2018; 392: 835–848.
25. Bauer T, Hochadel M, Brachmann J, et al. Use and outcome of radial versus femoral approach for primary PCI in patients with acute ST elevation myocardial infarction without cardiogenic shock: results from the ALKK PCI registry. *Catheter Cardiovasc Interv* 2015; 86: S8–14.
26. Marquis-Gravel G, Tremblay-Gravel M, Lévesque J, et al. Ultrasound guidance versus anatomical landmark approach for femoral artery access in coronary angiography: a randomized controlled trial and a meta-analysis. *J Interv Cardiol* 2018; 31: 496–503.
27. Serruys PW, de Jaegere P, Kiemeneij F, et al. A comparison of balloon-expandable-stent implantation with balloon angioplasty in patients with coronary artery disease. *N Engl J Med* 1994; 331: 489–495.
28. Fischman DL, Leon MB, Baim DS, et al. A randomized comparison of coronary-stent placement and balloon angioplasty in the treatment of coronary artery disease. Stent Restenosis Study Investigators. *N Engl J Med* 1994; 331: 496–501.
29. Chen MS, John JM, Chew DP, et al. Bare metal stent restenosis is not a benign clinical entity. *Am Heart J* 2006; 151: 1260–1264.
30. Morice M-C, Serruys PW, Sousa JE, et al. A randomized comparison of a sirolimus-eluting stent with a standard stent for coronary revascularization. *N Engl J Med* 2002; 346: 1773–1780.
31. Moses JW, Leon MB, Popma JJ, et al. Sirolimus-eluting stents versus standard stents in patients with stenosis in a native coronary artery. *N Engl J Med* 2003; 349: 1315–1323.
32. Stone GW, Ellis SG, Cox DA, et al. A polymer-based, paclitaxel-eluting stent in patients with coronary artery disease. *N Engl J Med* 2004; 350: 221–231.
33. Urban P, Meredith IT, Abizaid A, et al. Polymer-free drug-coated coronary stents in patients at high bleeding risk. *N Engl J Med* 2015; 373: 2038–2047.
34. Gao L, Wang Y-B, Jing J, et al. Drug-eluting balloons versus new generation drug-eluting stents for the management of in-stent restenosis: an updated meta-analysis of randomized studies. *J Geriatr Cardiol* 2019; 16: 448–457.
35. Latib A, Colombo A, Castriota F, et al. A randomized multicenter study comparing a paclitaxel drug-eluting balloon with a paclitaxel-eluting stent in small coronary vessels: the BELLO (balloon elution and late loss optimization) study. *J Am Coll Cardiol* 2012; 60: 2473–2480.
36. Belkacemi A, Agostoni P, Nathoe HM, et al. First results of the DEB-AMI (drug eluting balloon in acute ST-segment elevation myocardial infarction) trial: a multicenter randomized comparison of drug-eluting balloon plus bare-metal stent versus bare-metal stent versus drug-eluting stent in primary percutaneous coronary intervention with 6-month angiographic, intravascular, functional, and clinical outcomes. *J Am Coll Cardiol* 2012; 59: 2327–2337.
37. Shahzad A, Kemp I, Mars C, et al. Unfractionated heparin versus bivalirudin in primary percutaneous coronary intervention (HEAT-PPCI): an open-label, single centre, randomised controlled trial. *Lancet* 2014; 384: 1849–1858.
38. Bonaca MP, Bhatt DL, Cohen M, et al. PEGASUS-TIMI 54 steering committee and investigators, 2015. Long-term use of ticagrelor in patients with prior myocardial infarction. *N Engl J Med* 2015; 372: 1791–1800. <https://doi.org/10.1056/NEJMoa1500857>
39. Windecker S, Latib A, Kedhi E, et al. Polymer-based or polymer-free stents in patients at high bleeding risk. *N Engl J Med* 2020; 382: 1208–1218.
40. Wallentin L, Becker RC, Budaj A, et al. Ticagrelor versus clopidogrel in patients with acute coronary syndromes. *N Engl J Med* 2009; 361: 1045–1057.
41. Prasugrel versus Clopidogrel in Patients with Acute Coronary Syndromes | NEJM [Internet]. [cited 2021 Oct 9]. Available from: <https://www.nejm.org/doi/full/10.1056/nejmoa0706482>.
42. Schüpke S, Neumann F-J, Menichelli M, et al. Ticagrelor or prasugrel in patients with acute coronary syndromes. *N Engl J Med* 2019; 381: 1524–1534.
43. Dewilde WJ, Oirbans T, Verheugt FW, et al. Use of clopidogrel with or without aspirin in patients taking oral anticoagulant therapy and undergoing percutaneous coronary intervention: an open-label, randomised, controlled trial. *The Lancet* 2013; 381: 1107–1115.
44. Gibson CM, Mehran R, Bode C, et al. Prevention of bleeding in patients with atrial fibrillation undergoing PCI. *N Engl J Med* 2016; 375: 2423–2434.
45. Cannon CP, Bhatt DL, Oldgren J, et al. Dual antithrombotic therapy with dabigatran after PCI in atrial fibrillation. *N Engl J Med* 2017; 377: 1513–1524.
46. Lopes RD, Heizer G, Aronson R, et al. Antithrombotic therapy after acute coronary syndrome or PCI in atrial fibrillation. *N Engl J Med* 2019; 380: 1509–1524.
47. Vranckx P, Valgimigli M, Eckardt L, et al. Edoxaban-based versus vitamin K antagonist-based antithrombotic regimen after successful coronary stenting in patients with atrial fibrillation (ENTRUST-AF PCI): a randomised, open-label, phase 3b trial. *Lancet* 2019; 394: 1335–1343.
48. Svilaas T, van der Horst ICC and Zijlstra F. Thrombus aspiration during percutaneous coronary intervention in acute myocardial infarction study (TAPAS)—study design. *Am Heart J* 2006; 151: 597.e1–597.e7.



49. Jolly SS, Cairns JA, Yusuf S, et al. Outcomes after thrombus aspiration for ST elevation myocardial infarction: 1-year follow-up of the prospective randomised TOTAL trial. *Lancet* 2016; 387: 127–135.
50. Morishima I, Sone T, Okumura K, et al. Angiographic no-reflow phenomenon as a predictor of adverse long-term outcome in patients treated with percutaneous transluminal coronary angioplasty for first acute myocardial infarction. *J Am Coll Cardiol* 2000; 36: 1202–1209.
51. Rezkalla SH, Stankowski RV, Hanna J, et al. Management of No-reflow phenomenon in the catheterization laboratory. *JACC Cardiovasc Interv* 2017; 10: 215–223.
52. Baim DS, Wahr D, George B, et al. Randomized trial of a distal embolic protection device during percutaneous intervention of saphenous vein aorto-coronary bypass grafts. *Circulation* 2002; 105: 1285–1290.
53. Stone GW, Rogers C, Hermiller J, et al. Randomized comparison of distal protection With a filter-based catheter and a balloon occlusion and aspiration system during percutaneous intervention of diseased saphenous vein aorto-coronary bypass grafts. *Circulation* 2003; 108: 548–553.
54. Mauri L, Cox D, Hermiller J, et al. The PROXIMAL trial: proximal protection during saphenous vein graft intervention using the proxis embolic protection system: a randomized, prospective, multicenter clinical trial. *J Am Coll Cardiol* 2007; 50: 1442–1449.
55. Leborgne L, Cheneau E, Pichard A, et al. Effect of direct stenting on clinical outcome in patients treated with percutaneous coronary intervention on saphenous vein graft. *Am Heart J* 2003; 146: 501–506.
56. Ross AM, Gibbons RJ, Stone GW, et al. A randomized, double-blinded, placebo-controlled multicenter trial of adenosine as an adjunct to reperfusion in the treatment of acute myocardial infarction (AMISTAD-II). *J Am Coll Cardiol* 2005; 45: 1775–1780.
57. Räber L, Mintz GS, Koskinas KC, et al. Clinical use of intracoronary imaging. Part 1: guidance and optimization of coronary interventions. An expert consensus document of the European association of percutaneous cardiovascular interventions. *Eur Heart J* 2018; 39: 3281–3300.
58. Johnson T, Räber L, Mario CD, et al. Clinical use of intracoronary imaging. Part 2: acute coronary syndromes, ambiguous coronary angiography findings, and guiding interventional decision-making: an expert consensus document of the European Association of Percutaneous Cardiovascular Interventions [Internet]. *EuroIntervention*. [cited 2021 Feb 11]. Available from: <https://eurointervention.pronline.com/article/clinical-use-of-intracoronary-imaging-part2-acute-coronary-syndromes-ambiguous-coronary-angiography-findings-and-guiding-interventional-decision-making-an-expert-consensus-document-of-the-european-association-of-percutaneous-cardiovascular-interventions>.
59. Thiele H, Zeymer U, Neumann F-J, et al. Intraaortic balloon support for myocardial infarction with cardiogenic shock. *N Engl J Med* 2012; 367: 1287–1296.
60. Thiele H, Zeymer U, Thelemann N, et al. Intraaortic balloon pump in cardiogenic shock complicating acute myocardial infarction. *Circulation* 2019; 139: 395–403.
61. Schrage B, Ibrahim K, Loehn T, et al. Impella support for acute myocardial infarction complicated by cardiogenic shock. *Circulation* 2019; 139: 1249–1258.
62. Alushi B, Douedari A, Froehlig G, et al. Impella versus IABP in acute myocardial infarction complicated by cardiogenic shock. *Open Heart* 2019; 6: e000987.
63. Meneveau N, Séronde MF, Descotes-Genon V, et al. Immediate versus delayed angioplasty in infarct-related arteries with TIMI III flow and ST segment recovery: a matched comparison in acute myocardial infarction patients. *Clin Res Cardiol* 2009; 98: 257–264.
64. Ke D, Zhong W, Fan L, et al. Delayed versus immediate stenting for the treatment of ST-elevation acute myocardial infarction with a high thrombus burden. *Coron Artery Dis* 2012; 23: 497–506.
65. Pascal J, Veugeois A, Slama M, et al. Delayed stenting for ST-elevation acute myocardial infarction in daily practice: a single-centre experience. *Can J Cardiol* 2016; 32: 988–995.
66. Kelbæk H, Høfsten DE, Køber L, et al. Deferred versus conventional stent implantation in patients with ST-segment elevation myocardial infarction (DANAMI 3-DEFER): an open-label, randomised controlled trial. *Lancet* 2016; 387: 2199–2206.
67. Belle L, Motreff P, Mangin L, et al. Comparison of immediate With delayed stenting using the minimalist immediate mechanical intervention approach in acute ST-segment-elevation myocardial infarction: the MIMI study. *Circ Cardiovasc Interv* 2016; 9: e003388.
68. Qiao J, Pan L, Zhang B, et al. Deferred versus immediate stenting in patients With ST-segment elevation myocardial infarction: a systematic review and meta-analysis. *J Am Heart Assoc [Internet]*. 2017 Mar 8 [cited 2020 Jul 31]; 6: e004838. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5524015/>.
69. Park D-W, Clare RM, Schulte PJ, et al. Extent, location, and clinical significance of non-infarct-related coronary artery disease among patients with ST-elevation myocardial infarction. *JAMA* 2014; 312: 2019–2027.
70. Wald DS, Morris JK, Wald NJ, et al. Randomized trial of preventive angioplasty in myocardial infarction. *N Engl J Med* 2013; 369: 1115–1123.
71. Gershlick AH, Khan JN, Kelly DJ, et al. Randomized trial of complete versus lesion-only revascularization in patients undergoing primary percutaneous coronary intervention for STEMI and multivessel disease: the CvLPRIT trial. *J Am Coll Cardiol* 2015; 65: 963–972.
72. Høfsten DE, Kelbæk H, Helqvist S, et al. The third DANish study of optimal acute treatment of patients with ST-segment elevation myocardial infarction: ischemic postconditioning or deferred stent implantation versus conventional primary angioplasty and complete revascularization versus treatment of culprit lesion only: rationale and design of the DANAMI 3 trial program. *Am Heart J* 2015; 169: 613–621.
73. Engstrøm T, Kelbæk H, Helqvist S, et al. Complete revascularisation versus treatment of the culprit lesion only in patients with ST-segment elevation myocardial infarction and multivessel disease (DANAMI-3—PRIMULTI): an open-label, randomised controlled trial. *Lancet* 2015; 386: 665–671.

74. Mehta SR, Wood DA, Storey RF, et al. Complete revascularization with multivessel PCI for myocardial infarction. *N Engl J Med* 2019; 381: 1411–1421.
75. Elgendy IY, Mahmoud AN, Kumbhani DJ, et al. Complete or culprit-only revascularization for patients With multivessel coronary artery disease undergoing percutaneous coronary intervention: a pairwise and network meta-analysis of randomized trials. *JACC Cardiovasc Interv* 2017; 10: 315–324.
76. Thiele H, Akin I, Sandri M, et al. PCI Strategies in patients with acute myocardial infarction and cardiogenic shock. *N Engl J Med* 2017; 377: 2419–2432.
77. Thiele H, Akin I, Sandri M, et al. One-Year outcomes after PCI strategies in cardiogenic shock. *N Engl J Med* 2018; 379: 1699–1710.
78. Pu J, Ding S, Ge H, et al. Efficacy and safety of a pharmacoinvasive strategy With half-dose alteplase versus primary angioplasty in ST-segment-elevation myocardial infarction. *Circulation* 2017; 136: 1462–1473.
79. La Scala E, Steffenino G, Dellavalle A, et al. Half-dose thrombolysis to begin with, when immediate coronary angioplasty in acute myocardial infarction is not possible. *Ital Heart J* 2004; 5: 678–683.
80. Lemkes JS, Janssens GN, van der Hoeven NW, et al. Coronary angiography after cardiac arrest without ST-segment elevation. *N Engl J Med* 2019; 380: 1397–1407.
81. Lemkes JS, Janssens GN, van der Hoeven NW, et al. Coronary angiography after cardiac arrest without ST segment elevation: one-year outcomes of the COACT randomized clinical trial. *JAMA Cardiology* 2020; 5: 1358–1365.
82. Kern KB, Radsel P, Jentzer JC, et al. Randomized pilot clinical trial of early coronary angiography versus No early coronary angiography after cardiac arrest without ST-segment elevation: the PEARL study. *Circulation* 2020; 142: 2002–2012.
83. Overview | Acute coronary syndromes | Guidance | NICE [Internet]. NICE; [cited 2021 Oct 26]. Available from: <https://www.nice.org.uk/guidance/ng185>.