

Timely Reperfusion in STEMI: A Closed-Loop Audit of Guideline Compliance and Practice Improvements

C. Murray, J. Carey, R. Karlsson, I. Pearson.

Cardiology Department, St James's Hospital, James's St., Saint James, Dublin 8, Ireland.

Abstract

Aim

Timely reperfusion is vital in STEMI care to reduce mortality. An initial audit showed patients transferred from emergency departments outside Dublin often exceeded the 120-minute reperfusion target. In response, Dublin Mid Leinster protocols were updated to recommend pre-transfer thrombolysis. This study evaluates the impact of these changes on reperfusion times and outcomes.

Methods

This observational study included STEMI patients admitted to St. James's Hospital from 2021–2023, compared to a prior cohort (2017–2020). The primary outcome was time from first ECG to reperfusion. Secondary outcomes included thrombolysis rates, success (TIMI 2/3 flow on angiography) and safety.

Results

Among 1,301 patients, the median ECG-to-reperfusion time among patients transferred from outside Dublin fell from 124 minutes (IQR 96–166) to 113 minutes (IQR 78–151) ($p < 0.0001$), while the proportion achieving reperfusion within 120 minutes increased from 235/507 (46.4%) to 308/530 (58.1%). Overall thrombolysis use increased from 27/1161 (2.3%) to 131/1301 (10.1%). Among thrombolysed patients, 85/131 (64.9%) achieved successful reperfusion and severe bleeding occurred in 2/131 (1.5%). Mapping demonstrated markedly lower rates of timely reperfusion at the periphery of the DML region.

Discussion

A regional protocol promoting thrombolysis substantially increased thrombolysis utilisation and improved overall timely reperfusion among STEMI patients transferred from outside Dublin. Persistent geographical disparities support further optimisation of regional pathways and consideration of prehospital thrombolysis strategies.

Introduction

Acute ST-segment elevation myocardial infarction (STEMI) is a life-threatening emergency that requires timely reperfusion to minimise myocardial damage and mortality. Primary percutaneous coronary intervention (PPCI) is now the gold standard for STEMI treatment worldwide, offering superior outcomes compared to chemical thrombolysis, which is now largely reserved for situations where PPCI cannot be delivered within the recommended timeframes¹. This transition was driven by evidence showing thrombolysis has lower reperfusion rates and a higher risk of major bleeding, including intracranial haemorrhage (1–2%)^{2,3}.

International guidelines recommend PPCI within 120 minutes of first medical contact (FMC). If this cannot be achieved, thrombolysis should be administered within 10 minutes of FMC, followed by urgent transfer to a PCI centre¹. In Ireland, these principles were formalised in the 2012 Acute Coronary Syndrome (ACS) programme, which estimated based on travel times that PPCI would be possible for 80% of STEMI cases, with thrombolysis for the remaining 20%⁴.

St. James's Hospital (SJH) serves as the designated PPCI centre for the Dublin Mid Leinster (DML) region, which encompasses a broad area including Wexford General Hospital (WGH), St. Luke's General Hospital Kilkenny (SLK), the Midlands Regional Hospitals in Tullamore (MRHT), Mullingar (MRHM) and Portlaoise (MRHP), as well as Naas General Hospital (NGH), Tallaght University Hospital (TUH), St. Vincent's University Hospital (SVUH), St. Columcille's, and St. Michael's. While some Dublin hospitals manage STEMI during weekday hours, the majority of patients are transferred to SJH. Currently, thrombolysis is only administered within hospitals, with no system in place for prehospital delivery.

The critical importance of timely reperfusion in STEMI care cannot be overstated, given the well-established link between treatment delays and increased mortality⁵. However, meeting the 120-minute target remains challenging due to geographic and logistical constraints. The first phase of this audit, published in 2022, highlighted these issues by showing that the median time to reperfusion for patients transferred from all EDs outside Dublin exceeded the 120-minute benchmark⁶. Similarly, even some patients transported directly by ambulance from the field experienced delays beyond recommended timeframes, such as in the regions served by MRHM and WGH. Additionally, thrombolysis rates fell well below the ACS programme's projected 20%, with only 2.3% of patients receiving thrombolysis over the three-year period⁶.

In response, SJH revised its protocols: patients from outside Dublin EDs were considered for thrombolysis prior to transfer, and ambulance patients with anticipated transfers over 90 minutes were advised to receive thrombolysis locally. This study aimed to complete the audit cycle by evaluating whether these interventions have improved STEMI care in the Dublin Mid

Leinster (DML) region. The ultimate goal is to enhance timely reperfusion rates, ensure adherence to both national and international guidelines, and optimise outcomes for STEMI patients across the region.

Methods

This observational study included all patients admitted to St. James's Hospital (SJH) with confirmed STEMI from January 1, 2021, to January 1, 2024, and compared them to a prior audit cohort from June 30, 2017, to June 30, 2020. Data were sourced from the SJH PPCI database (via the National Heartbeat Portal), supplemented by electronic hospital records, and cross-checked for accuracy. The PPCI database includes 62 mandatory data points per patient, with data verified by the cardiology team and a specialist nurse, and reported to NOCA.

The primary outcome was time from first ECG (used as a surrogate for first medical contact) to reperfusion across cohorts. Secondary outcomes included thrombolysis rates and success (TIMI 2/3 flow on initial angiography), safety (severe bleeding causing hemodynamic compromise or intracranial haemorrhage), PCI timing, timeliness of thrombolysis for patients initially routed to local EDs, and mean transfer times for direct field transfers. Transfer times were estimated via Google Maps for STEMI locations outside Dublin at 1 PM and 1 AM and then averaged for consistency. Additionally, a regional map displayed the pickup locations of patients transported by ambulance from the field, with green markers indicating those who achieved reperfusion within 120 minutes and red markers showing those who did not (figure 3).

As an observational study, no clinical interventions were conducted so ethical approval was not required per local policy, but formal authorization was obtained from the SJH Research and Innovation department. Outcomes were compared to the 2017–2020 audit data.

Data analysis was carried out using SPSS v28. Descriptive statistics (median, N, IQR) were reported, and differences between referral regions assessed via independent samples t-tests. Between-period comparisons of overall ECG-to-reperfusion time were performed using the Mann-Whitney U test, given the non-normal distribution of reperfusion times.

Results

Between 2021 and 2023, 1,301 STEMI patients were admitted to SJH, compared with 1,161 in 2017–2020. Most patients (53.7%) were transferred directly by ambulance from the field,

40.3% were transferred from another hospital emergency department (20.4% from outside Dublin), and 3.8% self-presented.

When all reperfusion strategies were considered together among patients transferred from outside Dublin, the overall median ECG-to-reperfusion time decreased from 124 minutes (IQR 96–166) in 2017–2020 to 113 minutes (IQR 78–151) in 2021–2023 ($p < 0.0001$). Similarly, the proportion of patients achieving reperfusion within 120 minutes increased from 46.4% (235/507) to 58.1% (308/530). This improvement appeared to be driven predominantly by increased use of thrombolysis, with thrombolysis accounting for 4.5% (23/507) of reperfusion strategies in 2017–2020 compared with 23.3% (123/530) in 2021–2023.

Despite this improvement in overall reperfusion performance, median ECG-to-reperfusion times among patients who did not receive thrombolysis remained largely unchanged and continued to exceed 120 minutes for all transfers from emergency departments outside Dublin. Times were longest for WGH (4:23, IQR 0:57) and SLK (3:38, IQR 2:46), with the Midlands hospitals also remaining above target: MRHT (2:24), MRHM (2:35), and MRHP (2:47). The median time for NGH remained above guideline recommendations at 2:01 (IQR 1:17), whereas the Dublin hospitals SVUH and TUH were both just within the 120-minute threshold at 1:59 (IQR 1:00) and 1:59 (IQR 0:54), respectively. No significant differences in reperfusion times were observed across referral regions compared with 2017–2020 (all $p > 0.05$) (Table 1).

Thrombolysis rates increased substantially across all emergency department referral regions. At WGH, rates increased from 51.7% (2017–2020) to 80% (2021–2024), at SLK from 20.1% to 61.2%, and in all Midlands hospitals from <5% to >30%. This data is summarised in Table 1 below. Overall, 131/1301 (10.1%) patients received thrombolysis in 2021–2024 versus 27/1161 (2.3%) in 2017–2020. This trend is illustrated below (Image 1). Among these 131 patients, 85 (64.9%) were deemed to have achieved successful reperfusion (TIMI 2/3 flow on initial angiography). Severe bleeding occurred in 2/131 (1.5%), with one fatal case. In terms of subsequent interventions, 111/131 (84.7%) underwent PCI directly on arrival, while the remaining 20/131 (15.3%) proceeded to early invasive angiography. Notably, 17/131 patients were identified in the field and directed to a local ED for thrombolysis based on their predicted travel time to SJH (versus 0/27 thrombolysed patients 2017–2020), with a median door-to-thrombolysis time of 34 min (IQR 26–55).

STEMI patients transferred from another hospital Emergency Department						
		ECG to reperfusion time 2021-2024		ECG to reperfusion time 2017-2020		
Region	Referring hospital distance from SJH (km)	Transfer from hospital ED (not thrombolysed): Median time to reperfusion – hr:min (IQR) [N]	Proportion of those transferred from ED administered thrombolysis	Transfer from hospital ED (not thrombolysed): Median time to reperfusion hr:min (IQR) [N]	Proportion of those transferred from ED administered thrombolysis	P values (two-sample t-test)
WGH	146	4:23 (0:57) [N=9]	36/45 (80%)	4:06 (2:42) [N=14]	15/29 (51.7%)	0.78
SLK	123	3:38 (2:46) [N=20]	30/49 (61.2%)	3:36 (1:57) [N=23]	6/29 (20.1%)	0.92
MRHT	97.7	2:24 (0:48) [N=29]	22/51 (43.1%)	2:33 (1:20) [N=42]	2/44 (4.5%)	0.45
MRHM	80.7	2:35 (1:19) [N=29]	15/43 (34.9%)	2:33 (1:23) [N=44]	2/46 (4.3%)	0.87
MRHP	80.2	2:47 (1:03) [N=26]	13/39 (33.3%)	2:20 (0:50) [N=44]	0/44 (0%)	0.12
NGH	31.6	2:01 (1:17) [N=49]	7/57 (12.3%)	2:01 (1:01) [N=62]	0/62 (0%)	0.99
SVUH	9.8	1:59: (1:00) [N=51]	5/58 (8.6%)	1:46 (1:08) [N=54]	0/66 (0%)	0.21
TUH	7.9	1:59 (0:54) [N=71]	1/72 (1.4%)	1:48 (1:02) [N=83]	0/83 (0%)	0.15

Table 1: Time to reperfusion for STEMI patients transferred direct from the field.

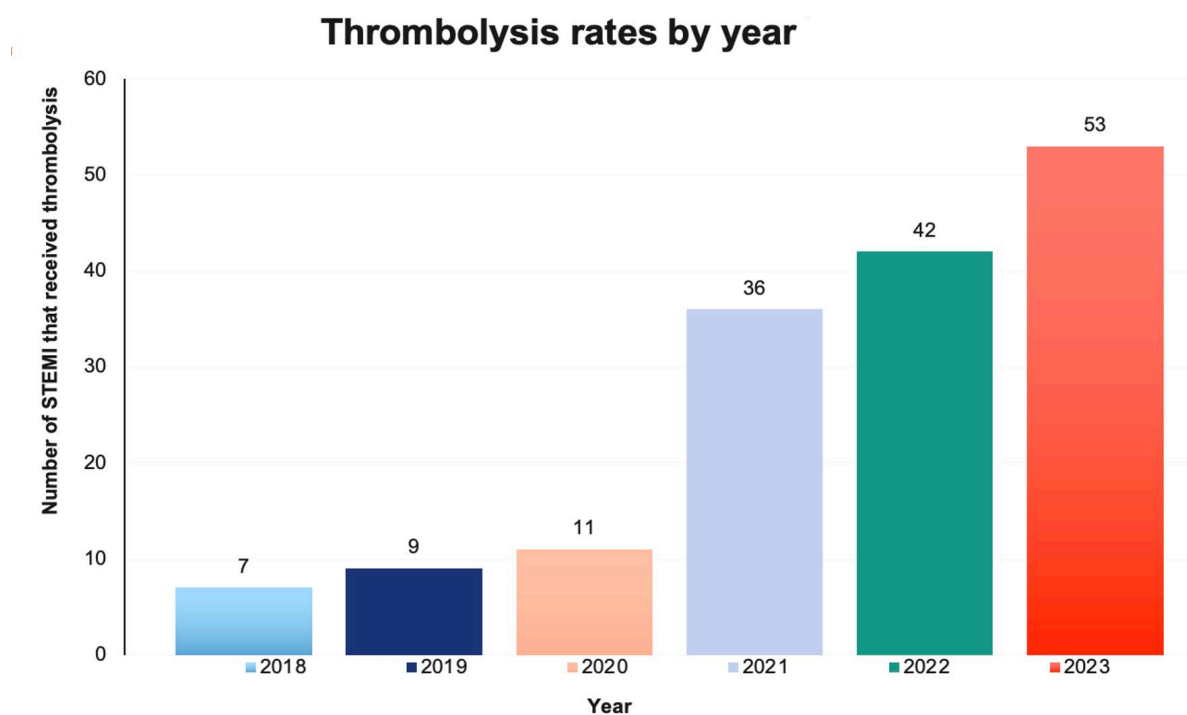


Image 1: Thrombolysis rates per year

For patients transferred directly via ambulance from the field, 2021–2023 data mirrored the 2017–2020 trends. Regions served by WGH and MRHM continued to exceed the 120-minute guideline, with median reperfusion times of 2:09 (IQR 0:37) and 2:10 (IQR 0:49), matching their longest mean travel times of 1:30 and 1:25, respectively. SLK had the third-longest travel time (1:20) and a median reperfusion of 2:00. Other regions showed median times of 1:50 (MRHP), 1:51 (MRHT), and 1:34 (NGH). In contrast, Dublin hospitals SVUH and TUH had shorter times at 1:24 and 1:17. These results are summarised in Table 2.

STEMI patients transferred direct from the field via ambulance			
	ECG to reperfusion time 2021-2023		ECG to reperfusion time 2017-2020
Region	Direct via Ambulance: Median time to reperfusion - <u>hr:min</u> (IQR) [N]	Mean time from location to SJH (google maps) (<u>hr:min</u>)	Direct via Ambulance: Median time to reperfusion - <u>hr:min</u> (IQR) [N]
WGH	2:09 (0:37) [N=30]	1:30	2:13 (0:43) [N=31]
SLK	2:00 (0:35) [N=46]	1:20	1:53 (0:32) [N=35]
MRHT	1:51 (0:24) [N=30]	1:10	1:53 (0:35) [N=24]
MRHM	2:10 (0:49) [N=27]	1:25	2:04 (1:06) [N=34]
MRHP	1:50 (0:37) [N=27]	1:11	1:45 (0:34) [N=28]
NGH	1:34 (0:26) [N=71]	0:45	1:31 (0:31) [N=95]
SVUH	1:24 (0:33) [N=126]	-	1:11 (0:25) [N=66]
TUH	1:17 (0:43) [N=72]	-	1:25 (0:41) [N=151]

Table 2: Time to reperfusion for STEMI patients transferred direct from the field.

Mapping analysis showed only 4/44 (9.1%) of patients picked up outside a defined area (“black line”) achieved reperfusion within 120 minutes (green marker), compared to 64/107 (59.8%) inside (image 2).

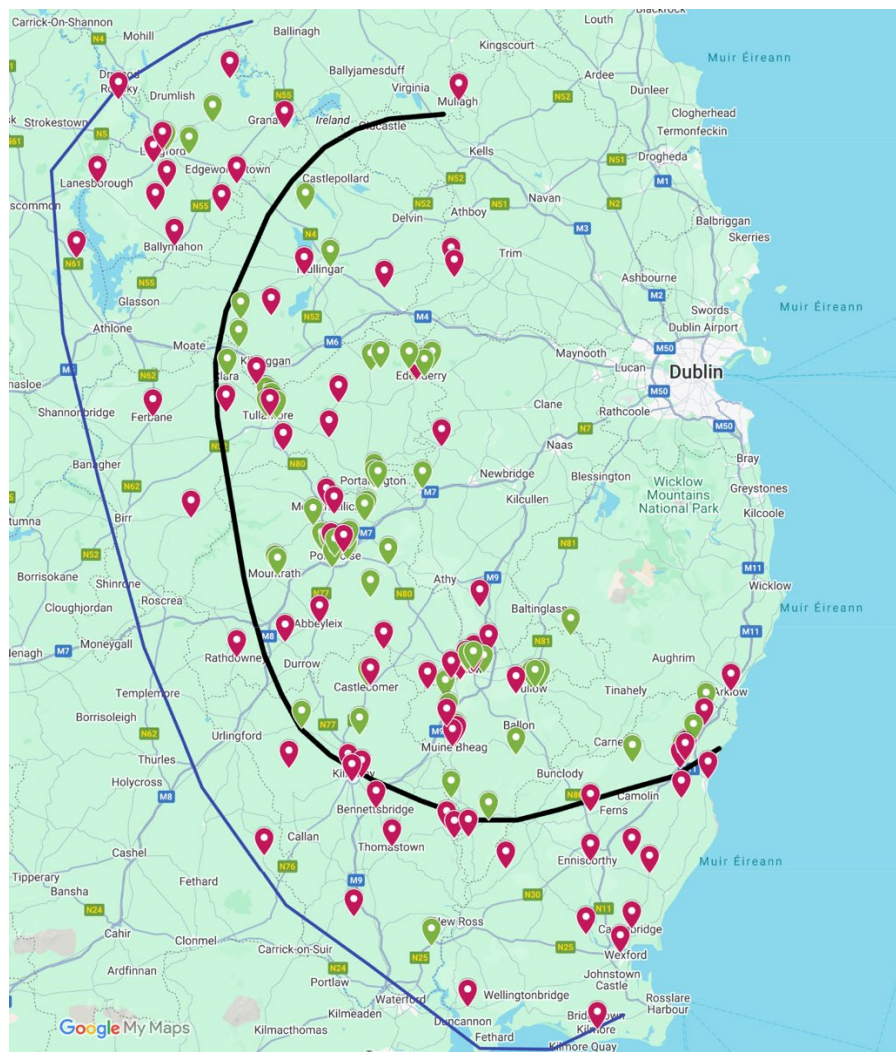


Image 2: Pickup locations for patients transferred direct from the field from hospitals outside of Dublin. Blue line: approximate DML border. Black line: line created to illustrate potential division outside of which patients may be a candidate for pre-hospital thrombolysis. Green marker: achieved reperfusion within 120 minutes. Red marker: Did not achieve reperfusion within 120 minutes

Discussion

The 2012 Acute Coronary Syndrome (ACS) programme sought to improve STEMI care nationwide, establishing PPCI as the gold standard. Following on from this, thrombolysis became infrequently used (27/1161 STEMI patients from 2017–2020), likely due to clinicians being overly optimistic about interhospital transfer times. This study completes the audit cycle of STEMI care in the DML region, demonstrating substantial improvements since the initial audit, particularly in thrombolysis use for patients unable to receive timely PPCI.

The median time from first ECG to reperfusion for patients who did not receive thrombolysis remained largely unchanged, continuing to exceed 120 minutes for transfers from outside Dublin, in line with previous findings. This suggests that delays are influenced by more than just transport times, suggesting other contributing factors within the pathway. This group accounted for 20.4% of STEMIs over three years. A two-sample t-test found no significant differences across referral regions compared to 2017–2020 (all $p > 0.05$), underscoring the need to consider thrombolysis in such patients when no contraindications exist. Importantly, when the impact of increased thrombolysis use was assessed at a system level, the overall median ECG-to-reperfusion time among patients transferred from outside Dublin fell from 124 to 113 minutes ($p < 0.0001$), while the proportion achieving reperfusion within 120 minutes increased from 46.4% to 58.1%. As primary PCI times remained unchanged ($p = 0.40$), this improvement is most likely attributable to the increased adoption of thrombolysis, which rose from 4.5% to 23.3% of reperfusion strategies in this cohort. These findings suggest that the protocol changes were associated with a meaningful improvement in the timeliness of reperfusion for patients at greatest risk of delayed PPCI.

Among patients transferred from another hospital ED, the proportion receiving thrombolysis increased significantly since the initial audit. This was most notable at WGH and SLK, where 80% and 61.2% of transferred patients, respectively, were thrombolysed before transfer. It is important to interpret these figures in light of the fact that 7–10% of patients are typically ineligible for thrombolysis due to contraindications⁷. Other hospitals outside Dublin also showed substantial improvement, with MRHM, MRHT, and MRHP increasing their rates from under 5% to over 30%, though still below ideal levels. These improved rates of appropriate thrombolysis administration highlight the positive impact of revised protocols on STEMI management across the region

Overall, there was a near fivefold increase in the overall rate of thrombolysis administration compared to the previous audit period (2.3% to 10.1%). However, this is still shy of the 20% projection based on travel times, that was set out in the original ACS programme in 2012. Of the 131 patients treated, 64.9% achieved successful reperfusion (TIMI 2/3 flow on initial angiography) illustrating the benefit of early reperfusion that can be achieved with thrombolysis. The rates of severe bleeding (1.5%) were low and consistent with published data⁸. Most (84.7%) still underwent facilitated PCI on arrival to SJH despite high rates of successful reperfusion.

For patients brought directly by ambulance to SJH, patterns mirrored the original audit, with transfers from WGH and MRHM still exceeding the 120-minute reperfusion target, consistent with their longest mean transfer times (1:30 and 1:25). Figure 3 illustrates a clear geographical

divide, where patients outside a defined boundary were much less likely to achieve timely PPCI, suggesting a threshold for either prehospital thrombolysis or diversion to the nearest ED for thrombolysis.

Building on this, there was a notable rise in patients proactively directed to local EDs for thrombolysis based on anticipated transfer times over 90 minutes—17 out of 131 patients compared to none in the previous audit period. However, door-to-needle times at these centres remained well above the ESC's recommended 10-minute target (median 34 min), underscoring the need for streamlined protocols and enhanced training at regional hospitals to improve timely thrombolysis delivery¹.

This study has several important limitations. Most notably, the 120-minute guideline target—defined by national and international standards—measures time from first medical contact (FMC) to reperfusion, typically starting at triage in regional emergency departments. As this specific timepoint was unavailable, first ECG time was used as a surrogate. According to ESC guidelines, FMC-to-ECG should be under 10 minutes, yet a recent Dublin audit found a median of 18 minutes, with only 28.8% achieving the ≤ 10 -minute benchmark^{1,9}. This further highlights that patients transferred from EDs outside Dublin are very likely to exceed the recommended PPCI time window, and even those transferred within Dublin may often fall outside it. A further methodological limitation relates to the estimation of ECG-to-reperfusion times in thrombolysis patients. In this analysis, thrombolytic drug administration was used as a surrogate for reperfusion, however, true myocardial reperfusion typically occurs 45–90 minutes later and may not occur at all in a proportion of patients⁹. Consequently, the reported ECG-to-reperfusion intervals for thrombolysed patients represent ECG-to-drug times and are likely to systematically underestimate the true reperfusion interval. Therefore, the observed improvement in timely reperfusion rates (46.4% to 58.1%) should be interpreted with caution. While it reflects a genuine acceleration in treatment delivery, it does not necessarily indicate a proportional increase in patients achieving myocardial reperfusion within 120 minutes. TIMI flow data on arrival to SJH provides some reassurance, with 64.9% of thrombolysed patients demonstrating TIMI 2/3 flow, but the precise timing of vessel-level reperfusion was not captured in this dataset. Additionally, this study focused on process measures (such as reperfusion times and TIMI flow) without assessing long-term clinical outcomes like mortality, reinfarction, or heart failure, which would offer a more complete view of patient benefit. Finally, incomplete data entry in the database limited the ability to determine the precise reasons for delays in many cases.

This closed-loop audit demonstrates that a regional protocol promoting pre-transfer thrombolysis can substantially increase thrombolysis utilisation and improve the proportion of patients receiving timely reperfusion. However, persistent delays to PPCI and prolonged

door-to-needle times indicate that further optimisation of both hospital and prehospital pathways remains necessary.

Declarations of Conflicts of Interest:

None declared.

Corresponding Author

Cian Murray,
Cardiology Department,
St James's Hospital,
James's St.,
Saint James,
Dublin 8,
Ireland.

E-Mail: murrac24@tcd.ie

References:

1. Byrne RA, Rossello X, Coughlan JJ, et al. 2023 ESC Guidelines for the management of acute coronary syndromes [published correction appears in Eur Heart J. 2024 Apr 1;45(13):1145. doi: 10.1093/eurheartj/ehad870.]. *Eur Heart J.* 2023;44(38):3720-3826. doi:10.1093/eurheartj/ehad191
2. Huynh T, Perron S, O'Loughlin J, et al. Comparison of primary percutaneous coronary intervention and fibrinolytic therapy in ST-segment-elevation myocardial infarction: bayesian hierarchical meta-analyses of randomized controlled trials and observational studies. *Circulation.* 2009;119(24):3101-3109. doi:10.1161/CIRCULATIONAHA.108.793745
3. Berkowitz SD, Granger CB, Pieper KS, et al. Incidence and predictors of bleeding after contemporary thrombolytic therapy for myocardial infarction. The Global Utilization of Streptokinase and Tissue Plasminogen activator for Occluded coronary arteries (GUSTO) I Investigators. *Circulation.* 1997;95(11):2508-2516. doi:10.1161/01.cir.95.11.2508
4. ACS programme model of care, 2012. <https://www.hse.ie/eng/services/publications/clinical-strategy-and-programmes/acute-coronary-syndrome-prog-moc.pdf>
5. Terkelsen CJ, Sørensen JT, Maeng M, et al. System delay and mortality among patients with STEMI treated with primary percutaneous coronary intervention. *JAMA.* 2010;304(7):763-771. doi:10.1001/jama.2010.1139

6. Murray C, Kumar R, Carey J, Ryan C, Pearson I. ST-Segment Elevation Myocardial Infarction (STEMI) Treatment Protocol: A 3 Year Clinical Audit. *Ir Med J*. 2022;115(No.10):691. Published 2022 Dec 15.
7. French JK et al. Prospective evaluation of eligibility for thrombolytic therapy in acute myocardial infarction. *BMJ*. 1996;312:1637–1641.
8. The International Study Group. In-hospital mortality and clinical course of 20 891 patients with suspected acute myocardial infarction randomised between alteplase and streptokinase with or without heparin. *Lancet*. 1990;336:71–75.
9. Shpigelman J, Proshkina A, Roman M, et al. Time to ECG diagnosis delays inter-hospital transfer to revascularization in STEMI patients presenting to a regional emergency department: a five-year audit. *Ir J Med Sci*. 2024;193(5):2203-2207.
doi:10.1007/s11845-024-03705-6
10. Rao SV, O'Donoghue ML, Ruel M, et al. 2025 ACC/AHA/ACEP/NAEMSP/SCAI Guideline for the Management of Patients With Acute Coronary Syndromes: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *J Am Coll Cardiol*. 2025;85(22):2135-2237.
doi:10.1016/j.jacc.2024.11.009