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Association of quality of care and long-term mortality risk for individuals presenting with ST-segment myocardial infarction (STEMI) by diabetes mellitus status: A nationwide cohort study

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ABSTRACT

Aims: This study aimed to assess how diabetes influences the quality of care and longer-term outcomes in contemporary STEMI cohorts.
Methods: We analysed 283,658 adults hospitalised with STEMI from the United Kingdom Myocardial Ischaemia National Audit Project (MINAP) registry between 2005 and 2019. This was linked with Office of National Statistics data to provide out of hospital mortality outcomes. We compared longer-term outcomes depending on diabetes status and assessed the effect of quality of care using the opportunity-based quality-indicator score (OBQI).
Results: Individuals with diabetes were older (median age 68.7 vs. 65.5), underwent percutaneous coronary intervention less frequently (60 % vs. 63 %) and were less likely to achieve a door-to-balloon time of < 60 min (69 % vs. 75 %) or < 120 min (89 % vs. 92 %). Their adjusted all-cause mortality risk was higher during follow-up, from 30 days (HR: 1.49, CI: 1.44–1.54), to up to 10 years of follow up (HR: 1.54, CI: 1.52–1.57), compared to individuals without diabetes. Excellent inpatient care was associated with lower mortality rates within individuals with diabetes (Diabetes: HR 0.56, CI: 0.50–0.64, No diabetes: HR 0.62, CI: 0.58–0.67).
Conclusions: Individuals with diabetes have a higher risk of long-term mortality after STEMI. They experience delays in angiography and receive lower quality inpatient care.

1. Introduction

Diabetes mellitus is a significant risk factor for ST-elevation myocardial infarction (STEMI), with an estimated prevalence of 10–20 % within this patient population[1]. With rates of diabetes estimated to increase up to 50 % by 2045[2], the proportion of STEMI patients presenting to hospital with diabetes is expected to increase[3].

In the last thirty years, STEMI management has evolved with timely primary percutaneous coronary intervention revolutionising management. Together with advances in medications, such as newer generation

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anti-platelet medications, the mortality and morbidity of STEMI within this patient cohort is improving[4].

Despite these advancements, individuals with diabetes, presenting with STEMI, have worse longer-term mortality, up to 5 years[5] compared to those without diabetes. Contemporary cohorts reporting on mortality beyond this timeframe is lacking. Moreover, there is evidence that, individuals with diabetes, receive lower quality inpatient care[6]. There is currently little evidence within the literature assessing how quality of inpatient care during index STEMI admission affects longer-term mortality outcomes within individuals with diabetes.

To investigate this within a contemporary cohort we used the Myocardial Ischaemia National Audit Project (MINAP) registry, linked to Office for National Statistics (ONS) mortality data, to compare in-hospital quality of care for STEMI patients by diabetes status and assess its impact on long-term mortality risk.

2. Methods

2.1. Study design

We used the MINAP registry, a prospective national registry of patients admitted to UK hospitals with an acute coronary syndrome. The MINAP registry is one the world's largest AMI registries and consists of 130 variables, including baseline demographics, clinical characteristics, comorbidities, management strategies, pharmacotherapy, in-hospital clinical outcomes, and discharge diagnosis[7]. Data are submitted by hospital clinical staff, and approximately 90,000 pseudonymised records annually are uploaded to the National Institute for Cardiovascular Outcomes Research (NICOR). In-hospital mortality is recorded in the MINAP registry, but for out-of-hospital outcomes we used linked ONS data, which is the UK's independent provider of official statistics, regularly collecting data on every death registered in the UK, coding deaths according to the international classification of diseases (ICD-10) and cause of death from the medical certificate of cause of death.

2.2. Study population

We included participants admitted with a diagnosis of STEMI in any of the 230 participating hospitals in England and Wales between 01/01/2005 and 30/03/2019. The discharge diagnosis of STEMI was determined by local clinicians according to presenting history, clinical examination, and the results of in-patient investigations in keeping with the consensus document of the Joint European Society of Cardiology (ESC) and American College of Cardiology (ACC) Committee [8]. Participants' gender and ethnicity was self-reported during their inpatient admission. Participants were excluded if they had missing data for our key variables for investigation; diagnosis of diabetes, in-hospital mortality, major adverse cardiovascular events (composite of inpatient death and reinfarction) and cardiac mortality. Participants' index admission with STEMI was used for analysis purposes, with duplicate participant admissions excluded according to a unique National Health Service (NHS) number. Records with a missing NHS number were excluded. Mortality follow-up data was available from the ONS up 15/07/2021 via a single download (Fig. 1).

2.3. Subgroup Analysis

Subgroup analysis was performed to compare the processes of care and long-term survival of participants according to the MINAP categorisation of diabetic management strategy; diet treated, tablet treated, or insulin treated.

2.4. Outcomes

2.4.1. Primary

The primary outcome was all-cause mortality over the study period, with different end-points reported, specifically 30 day, 1 year, 5 year and 10 year mortality (where available). All-cause mortality was calculated from the date of admission with STEMI, as recorded in the MINAP registry, and the date of registration of death, as recorded by the ONS.

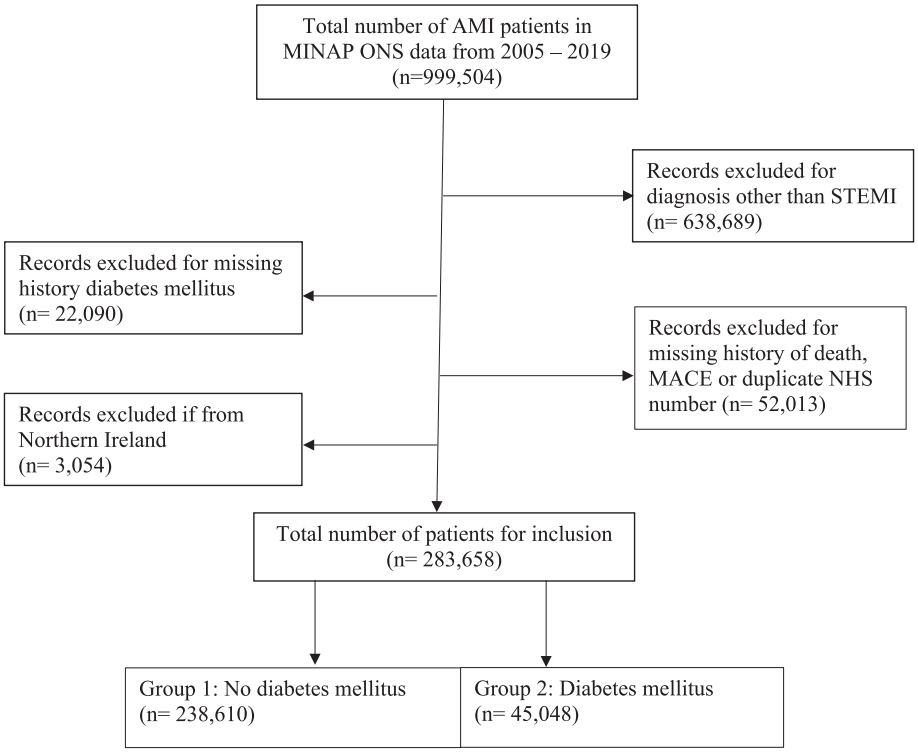


Fig. 1. STROBE diagram detailing exclusion criteria.

2.4.2. Secondary

Secondary outcomes of admission for STEMI participants were the opportunity-based quality indicator (OBQI) score, which comprises of inpatient prescription of aspirin, $P2Y_{12}$ inhibitors, statins, β-blockers, Angiotensin-converting enzyme inhibitors (ACEi) or Angiotensin receptor blockers (ARB) and referral for cardiac rehabilitation at the time of discharge[9]. These represent elements of the ESC quality metrics and form part of 2023 ESC AMI guidelines[10]. We classified the OBQI scores into four categories: 'excellent' refers to an OBQI (score of $\geq$ 90 and $\leq$ 100); 'good' ($\geq$80 and $<$ 90); 'fair' ($\geq$70 and $<$ 80), and 'poor' ($<$70) [11].

We also assessed the 2020 ESC Association for Acute Cardiovascular Care (ACVC) quality indicators for STEMI[12], including door-to-balloon times $<$ 60 and $<$ 120 min, whether patients were reperfused within 12 h of presentation and overall revascularisation strategy (PCI and CABG). This also includes whether patients had their left ventricular ejection fraction assessed if they received dual antiplatelet therapy or ACE inhibitors (for those with moderate (EF 30–49 %) and severe (EF $<$ 30 %) left ventricular systolic dysfunction) on discharge.

2.5. Statistical analysis

Demographics, clinical characteristics, and crude risks for adverse outcomes by the presence of diabetes were compared using Pearson's chi-square test for categorical variables. Continuous variables were compared using Student's *t*-test, if normally distributed, and using the Wilcoxon Rank Sum test or Kruskal-Wallis test if not. The normality of distribution was assessed using the Shapiro-Wilk test. Continuous variables are presented as medians and interquartile ranges (IQR) and categorical variables by proportions. Power estimations to evaluate mortality risk at 10 years were assessed using the power function, and our study had a power of 100 % to detect this difference. Multiple imputations with chained equations (MICE) were used to impute values for variables with missing data. MICE is the best practice when dealing with missing data and can provide unbiased estimates even when levels of missing data are significant and some protection when the pattern of 'missingness' is not random[13]. Kaplan-Meier curves were plotted and reported. Cox regression models were fitted (on ten imputed datasets), adjusted for; age, gender, year, hospital, ethnicity, heart rate, blood pressure, admission hospital, co-morbid conditions (hypertension, history of asthma or COPD, previous stroke, peripheral vascular disease, history of chronic kidney disease and smoking status), pharmacotherapy (prescription of low molecular weight heparin (LMWH), warfarin, aspirin, $P2Y_{12}$ inhibitor, statin, ACE inhibitors and β-blockers), Left ventricular ejection fraction, cardiac arrest, procedures including coronary angiography and revascularisation (by PCI or CABG) during admission, to calculate hazard ratios (HR) for mortality risks associated with diabetes; participants without diabetes as referent. Separate models were run, with different follow-up times, to generate hazard ratios for 30-day, 1-year, 5-year, 10-year and overall mortality during the study period. Further Kaplan-Meier curves were plotted for diabetes patients only, by OBQI score, this was landmarked with 30-day mortality removed to reflect the elements of OBQI parameters that are assessed on discharge.

We modelled an interaction term and outcome on 1-year mortality risk between the OBQI score and diabetes status. This was performed within a dataset extracted from our imputed dataset, running a logistic regression model, adjusted for the same variables as included in the previously described Cox-model, then by applying the margins function to calculate adjusted 1-year mortality risk. This was landmarked with mortality within 30-days of admission excluded to reflect that elements of OBQI parameters that are assessed on discharge.

We modelled potential lives saved if patients from each diabetes status category received excellent care. We used the prior logistic regression model to obtain the standard error for each combination of quality of care, which would act as our 95 % confidence intervals. We then used the adjusted 1-year mortality from the margins function for each category of OBQI score to calculate the difference in adjusted 1-year mortality for each quality of care group between excellent care and the alternate quality of care groups. We then applied the difference in adjusted mortality between different OBQI score categories to the population at risk, to model the potential mortality benefit at 1 year of receiving "excellent" care according to the OBQI score.

Stata 18.0 was used for all analyses and an alpha level of 0.05 was used throughout.

3. Results

After applying the relevant exclusion criteria, of individuals admitted to hospitals in England and Wales with an acute myocardial infarction, there were 283,658 (28 %) people with a diagnosis of STEMI (Fig. 1). Of these, 45,048 (16 %) people had a diagnosis of diabetes. The median duration of follow up for participants included in the study was 6.24 years (IQR: 3.1–10.1 years).

3.1. Demographic comparison between STEMI participants with and without diabetes mellitus

Individuals with diabetes were older (median age: 68.7 (IQR 58.5—77.8 years) vs. 65.5 (IQR 55.5—76.3 years), more likely to be female (32 % vs. 29 %, $p < 0.001$) and be of Asian ethnicity (13 % vs. 5 %, $p < 0.001$). Individuals with diabetes were also more likely to present with common cardiovascular risk factors including hypercholesterolemia (48 % vs. 26 %, $p < 0.001$), chronic kidney disease (7 % vs. 2 %, $p < 0.001$), and hypertension (65 % vs. 39 %, $p < 0.001$). Additionally, they were more likely to have had previous PCI (12 % vs. 5 %, $p < 0.001$) and CABG (6 % vs. 2 %, $p < 0.001$). During admission, individuals with diabetes were more likely to develop severe left ventricular systolic dysfunction (12 % vs. 8 %, $p < 0.001$) (Table 1).

3.2. Management strategies and unadjusted clinical outcomes for STEMI participants with and without diabetes mellitus

Individuals with diabetes were less likely to receive revascularisation by PCI (60 % vs. 63 %, $p < 0.001$). Their unadjusted MACE was higher (13 % vs. 8 %, $p < 0.001$) and they more commonly had a cardiovascular cause of death than for individuals without diabetes (51 % vs. 44 %, $p < 0.001$) (Table 1).

3.3. Quality indicators for STEMI participants with and without diabetes mellitus

Individuals with diabetes were less likely to achieve a door-to-balloon time within 1 h (69 % vs. 75 %, $p < 0.001$) and 2 h (89 % vs. 92 %, $p < 0.001$). Upon discharge, individuals with diabetes were less likely to be referred to cardiac rehabilitation (82 % vs. 87 %, $p < 0.001$). Overall quality of care received by individuals with diabetes was lower, as assessed by the OBQI score (87.4 vs. 88.0, $p < 0.001$) (Table 1).

3.4. Long-term mortality analysis

Individuals with diabetes had a higher unadjusted and adjusted mortality at each follow up timepoint from 30 days to up to 10 years (Table 1) (Table 2, Fig. 2). Mortality was highest for insulin treated participants compared to diet treated and tablet treated participants across all years of follow-up (ESM Table S1, ESM Fig. S1).

3.5. Subgroup quality of care analysis

Within individuals with diabetes, higher quality inpatient care, as derived from the OBQI score, led to a lower risk of long-term mortality, 'good' care (HR 0.80, CI 0.71–0.91, $p < 0.001$) and 'excellent' care (HR

Table 1
Demographic, management strategy, quality of care and outcome comparison between participants with and without diabetes mellitus.

Variable	No diabetes (*N* = 238,610)	Diabetes (*N* = 45,048)	*p* value
Age (years)	65.5 (55.5–76.3)	68.7 (58.5–77.8)	<0.001
Female	68,859/238,610 (29)	14,285/45,048 (32)	<0.001
BMI (kg/m^2)	26.5 (23.8–29.7)	28.4 (25.1–32.3)	<0.001
Ethnicity			<0.001
White	112,392/119,398 (94)	21,404/25,222 (85)	
Asian	5,846/119,398 (5)	3,356/25,222 (13)	
Black	869/119,398 (1)	372/25,222 (1)	
Mixed	291/119,398 (0)	90/25,222 (0)	
Killip Class			<0.001
Basal crepitations	9,837/109,731 (9)	2,790/23,475 (12)	
Pulmonary oedema	3,851/109,731 (4)	1,504/23,475 (6)	
Cardiogenic shock	3,686/109,731 (4)	1,254/23,475 (5)	
GRACE score			<0.001
High risk (>140)	67,717/101,545 (67)	16,033/21,720 (74)	
Intermediate risk (109–140)	27,624/101,545 (27)	4,794/21,720 (22)	
Low risk (<109)	6,204/101,545 (6)	893/21,720 (4)	
Previous smoker	61,973/227,845 (27)	13,493/42,277 (32)	<0.001
Current smoker	88,058/227,845 (39)	11,961/42,277 (28)	<0.001
CCF	4,440/218,336 (2)	2,058/40,858 (5)	<0.001
Hypercholesterolaemia	56,715/217,421 (26)	19,718/40,952 (48)	<0.001
Cerebrovascular disease	10,907/218,486 (5)	3,737/40,911 (9)	<0.001
CKD[a]	4,761/217,685 (2)	2,893/40,636 (7)	<0.001
History of angina	25,411/220,047 (12)	9,168/41,166 (22)	<0.001
Peripheral vascular disease	5,489/216,811 (3)	2,416/40,653 (6)	<0.001
Hypertension	87,031/222,117 (39)	27,226/41,836 (65)	<0.001
Asthma/COPD	25,910/217,448 (12)	5.512/40,844 (14)	<0.001
Previous AMI	22,941/222,192 (10)	8,912/41,590 (21)	<0.001
Previous PCI	11,417/219,413 (5)	4,756/41,071 (12)	<0.001
Previous CABG	4,591/219,474 (2)	2,276/41,169 (6)	<0.001
Family history of CAD	64,619/188,961 (34)	10,500/34,298 (31)	<0.001
Heart rate (bpm)	75 (64–89)	80 (68–95)	<0.001
Systolic BP (mmHg)	131 (114–150)	131 (114–151)	0.445
LV function[b]			<0.001
Good	58,976/173,112 (34)	9,857/33,236 (30)	
Moderate	51,842/173,112 (30)	10,460/33,236 (31)	
Severe	13,218/173,112 (8)	3,847/33,236 (12)	
Cardiac arrest	27,483/233,668 (12)	5,158/44,052 (12)	
Admission under cardiologist	191,907/235,233 (82)	35,869/44,296 (81)	0.003
Admission to cardiology ward[c]	209,756/236,643 (89)	38,217/44,635 (85)	<0.001
LMWH	90,701/197,918 (46)	17,595/36,723 (48)	<0.001
Fondaparinux	18,956/167,235 (11)	4,369/32,090 (14)	<0.001
Warfarin	6,970/194,499 (4)	1,614/36,158 (5)	<0.001
Unfractionated heparin	94,002/195,782 (48)	16,492/36,422 (45)	<0.001
Glycoprotein 2b/3a inhibitor	33,827/199,473 (17)	5,676/37,129 (15)	<0.001
Intravenous nitrate	45,139/194,629 (23)	8,759/36,189 (24)	<0.001
Furosemide	4,851/193,955 (3)	1,336/36,057 (4)	<0.001
MRAs	13,239/140,640 (9)	3,226/27,868 (12)	<0.001
Aspirin	232,539/237,633 (98)	43,537/44,834 (97)	<0.001
$P2Y_{12}$ inhibitors	202,988/230,902 (88)	38,271/43,688 (88)	0.069
Statins	205,878/236,497 (87)	39,486/44,656 (88)	<0.001
ACE inhibitors/ARBs	195,574/236,200 (83)	36,610/44,591 (82)	<0.001
β-blockers	200,345/236,254 (85)	37,219/44,600 (83)	<0.001
ICA	183,205/233,307 (79)	33,572/44,175 (76)	<0.001
PCI	131,411/208,699 (63)	24,179/40,419 (60)	<0.001
CABG surgery	2,288/180,404 (1)	724/33,086 (2)	<0.001
Revascularisation (CABG surgery/PCI)	161,029/235,150 (68)	29,430/44,510 (66)	<0.001
Reperfusion within 12 h of presentation	173,207/175,539 (99)	29,208/29,869 (98)	<0.001
Door-to-balloon time < 60 min	131,603/175,539 (75)	20,560/29,869 (69)	<0.001
Door-to-balloon time < 120 min	161,938/175,539 (92)	26,654/29,869 (89)	<0.001
Revascularization (PCI/CABG)	161,045/235,147 (68)	29,407/44,510 (66)	<0.001
Left ventricular ejection fraction assessed	124,039/173,097 (72)	24,142/33,220 (73)	<0.001
DAPT received on discharge	178,562/218,447 (82)	33,064/41,151 (80)	<0.001
ACE inhibitor or ARB on discharge for those with moderate and severe LVSD (%)	55,478/64,682 (86)	11,847/14,127 (84)	<0.001
OBQI			
Mean OBQI score	88.0	87.4	<0.001
Cardiac rehabilitation (%)	192,256/221,415 (87)	33,965/41,531 (82)	<0.001
In-hospital mortality	16,739/238,610 (7)	5,087/45,048 (11)	<0.001
30 day mortality	19,808/238,610 (8)	5,972/45,048 (13)	<0.001
1 year mortality	30,780/238,610 (13)	9,384/45,048 (21)	<0.001
5 year mortality	46,619/195,340 (24)	13,260/34,506 (38)	<0.001
10 year mortality	41,168/106,801 (39)	9,820/16,984 (58)	<0.001
Inpatient cardiac mortality	15,399/241,189 (6)	4,694/45,521 (10)	<0.001
Reinfarction	4,513/219,768 (2)	964/41,465 (2)	<0.001
Major bleeding	4,454/232,179 (2)	1,001/43,785 (2)	<0.001
MACE[d]	20,481/241,189 (8)	5,820/45,521 (13)	<0.001
Circulatory cause of death	36,733/82,906 (44)	11,232/22,144 (51)	<0.001

CABG: coronary artery bypass graft, LV function, left ventricular function, COPD; chronic obstructive pulmonary disease, MI; myocardial infarction, CCF; congestive cardiac failure, BMI; body mass index, GRACE; global registry of acute coronary events, IQR; interquartile range, bpm, beats per minute. LMWH; low molecular weight heparin, ICA: invasive coronary angiography, MRA; mineralocorticoid receptor antagonist, ACE: angiotensin-converting-enzyme, ARB; angiotensin receptor blockers, CABG; coronary artery bypass graft, PCI; percutaneous coronary intervention.

Continuous variables are expressed as median (IQR) and categorical variables as proportions (%). Denominators represent the total number of participants with a data point collected; numerators represent the number of those participants for whom the variable of interest was present. Cardiac arrest is a composite of both in-hospital and out of hospital cardiac arrests.

OBQI: Opportunity-based care score. The score consists of six evidence-based processes of care: prescription of aspirin, a thienopyridine inhibitor, a β-blocker, an ACE inhibitor, a hydroxymethylglutaryl-coenxyme A (HMG CoA) reductase enzyme inhibitor (statin) and enrolment onto a cardiac rehabilitation programme at the time of discharge. The score reflects the number of care opportunities fulfilled at each hospital (numerator) divided by the number of opportunities to provide care (denominator). Interventions that were contraindicated, not applicable or not indicated in or declined by individual participants were excluded from both the numerator and the denominator.

[a] Chronic kidney disease is recorded in the MINAP registry as a serum creatinine level chronically elevated above 200 μmol/l.

[b] Good left ventricular function was defined as an ejection fraction (EF) $\geq$ 50 %, moderate left ventricular function as an EF 30–49 % and severe left ventricular function as an EF $<$ 30 %.

[c] Admission to cardiology ward is a composite of admission to a coronary care unit or a general cardiology ward.

[d] MACE was defined as a composite endpoint of in-hospital death and reinfarction

Table 2
Survival analysis for people admitted with STEMI comparing outcomes in those with and without diabetes mellitus.

Outcomes	Adjusted hazard ratio for diabetes mellitus patients compared with patients without (95 % CIs)	*p* value
30-day mortality	1.49 (1.44–1.54)	<0.001
1-year mortality	1.48 (1.45–1.52)	<0.001
5-year mortality	1.53 (1.50–1.56)	<0.001
10-year mortality	1.54 (1.52–1.57)	<0.001
Overall mortality	1.54 (1.51–1.56)	<0.001

Adjusted hazard ratios are presented with 95% CIs, adjusted for: age, gender, year, hospital, ethnicity, heart rate, blood pressure, admission hospital, comorbid conditions (hypertension, history of asthma or COPD, history of CVA or PVD, history of CKD and smoking status), pharmacotherapy (prescription of low molecular weight heparin (LMWH), warfarin, aspirin, $P2Y_{12}$ inhibitor, statin, ACE inhibitors and β-blockers), Left ventricular ejection fraction, cardiac arrest, procedures including coronary angiography during admission and revascularisation (by PCI or CABG during admission). MACE is defined as composite endpoint of in-hospital death and reinfarction.

0.56, CI 0.50–0.64, p < 0.001) (Fig. 3I). Provision of 'good' care resulted in similar mortality benefits for all participants within the study (Fig. 3II-V). Within our multivariate model, 'Excellent' care was associated with better outcomes similarly in participants with and without diabetes (Fig. 3I, 3 V).

Assessing the effect of the individual interaction between quality of care and diabetic status, there was a stepwise decrease in risk of 1 year mortality in all groups as quality of care improved from poor to good and excellent care (ESM Table S2). There was a positive association between OBQI and DM status in our interaction analysis. Moreover, subgroup analysis revealed that individuals requiring insulin had the highest risk of 1 year mortality within each OBQI category compared to all other diabetic and non-diabetic groups (ESM Fig. S2).

Further analysis revealed that despite receiving 'excellent' care, individuals with diabetes still had an increased mortality risk compared to those without diabetes (ESM Table S3, ESM Fig. S3). Modelling potential lives saved if all participants received 'excellent' care showed there is an anticipated survival benefit in improving care for participants receiving 'poor', 'fair' and 'good' care and proportionally this was greater in participants with diabetes. The improved difference in mortality risk was similar in each group of participants with diabetes but tablet treated individuals had the highest number of potential lives saved. Overall 2,076 lives could have been saved if all patients received excellent care through our study period (ESM Table S3).

4. Discussion

Our analysis of over 280,000 UK STEMI individuals with a median follow up of 6.24 years reveals important disparities in care and outcomes between individuals with and without diabetes. Participants with diabetes, at the time of first STEMI, during our study period, were older, had more comorbidities, and were less likely to undergo invasive coronary revascularisation. Individuals with diabetes were more likely to experience a delay in door-to-balloon time and they received fewer referrals to cardiac rehabilitation. This difference was particularly evident within individuals treated with insulin. Participants with diabetes had an 54 % greater overall risk of mortality within our study duration compared to individuals without diabetes. Importantly we show that this mortality risk remains unchanged after excluding participants that died within the first 30 days of admission, suggesting the elevated mortality risk is not just mediated by early inpatient and post-discharge mortality, rather it extends over a significant follow-up period, of up to 10 years. Crucially, our modelling suggests that improved inpatient care quality could have resulted in thousands of lives-saved for this cohort. Despite the importance of excellent inpatient care, even in individuals that achieve this, the presence of diabetes is still an important predictor of elevated long-term mortality.

Cardiovascular disease is the leading cause of mortality and morbidity within individuals with diabetes[14]. This is suggested to be multifactorial, contributed by accelerated atherosclerosis[15], alongside atypical presentation of myocardial infarction symptoms and higher prevalence of risk factors such as obesity, hypertension, hyperlipidaemia and CKD[14]. Our study revealed a similar association of these risk factors within our diabetic cohort. The prevalence of these comorbid conditions is important in the interpretation of our mortality differences, but also in the interpretation of our analysis of quality of care. For example, CKD increases bleeding risk from invasive therapy[16] and may deter the use of nephrotoxic contrast media, leading to more caution in undergoing invasive procedures[17]. Additionally, individuals with CKD often have complex multi-vessel coronary artery disease which may be less amenable to PCI[18].

Previous smaller studies have reported mortality disparities in STEMI for individuals with diabetes. Megaly et al. showed a 7 % higher risk in 5 year mortality within individuals with diabetes[5]. Similarly, Spione et al. reported worse 10 year mortality in a cohort of 1,498 people[19]. Our findings, from a much larger, contemporary, national cohort, reveals a higher mortality disparity within individuals with diabetes than previously shown and reveals that insulin-treated participants have particularly poorer long-term outcomes within the diabetic cohort.

Considering the reasons behind this, it is important to highlight that this cohort in our study is heterogenous and contains both participants with type 1 and 2 diabetes. The use of exogenous insulin indicates high insulin resistance which results in accelerated atherosclerosis and an increased risk of in-stent restenosis[20]. Additionally, participants with type 2 diabetes on insulin are likely to have a longer duration of disease, poorer historic glycaemic control and multiple comorbidities compared

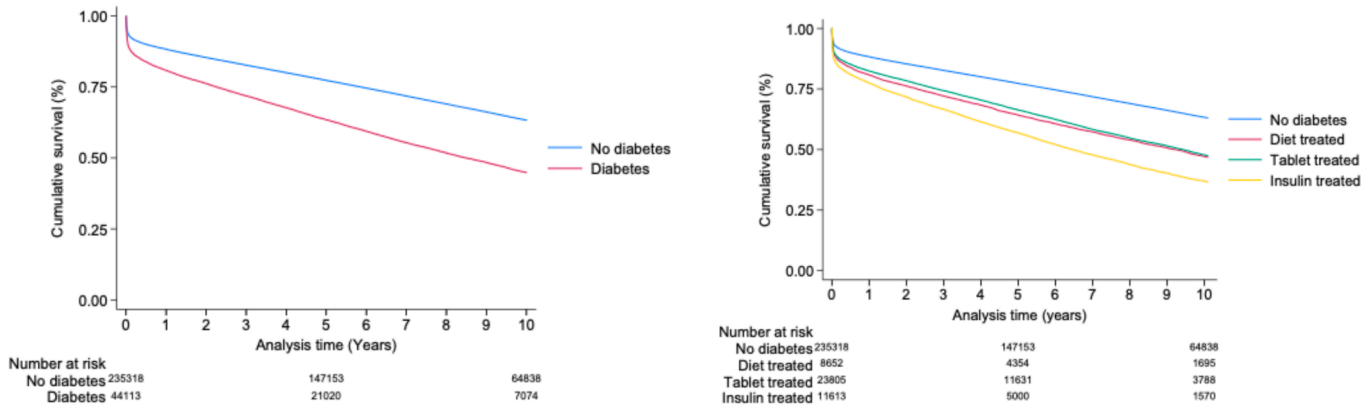


Fig. 2. Kaplan-Meier Survival Curves for individuals with diabetes mellitus compared to those without.

to other individuals with type 2 diabetes. Overall, individuals with type 1 diabetes have been shown to have worse outcomes post AMI and receive less revascularisation compared to individuals with type 2 diabetes[21].

There were delays in participants with diabetes receiving emergency PCI compared to those without diabetes in our study, as evidenced by them more often failing to achieve target door-to-balloon times. Previous studies have linked slower door-to-balloon times to higher mortality risk. This is suspected to be due to increased ischemic time resulting in greater myocardial damage, greater mechanical complications, greater risk of ventricular arrhythmias and greater risk of post-STEMI left ventricular systolic dysfunction[22]. There are several possible explanations around why this delay occurs. Firstly, it has been shown that individuals with diabetes present with less classical STEMI symptoms which can lead to a delay in diagnosis and a delayed inter-hospital transfer if required[23]. Secondly, as shown in our analysis, individuals with diabetes initially present more acutely unwell, with a higher Killip class. Killip class correlates with a slower door-to-ballon time, as patients often need stabilising prior to intervention[24]. Additionally, participants with diabetes present more commonly with comorbidities such as PVD and CKD which can complicate arterial access[25]. Pattern of coronary artery disease differs within individuals with diabetes with increased multi-vessel diffuse disease, calcific or bifurcation disease creating more complex procedures[26].

We show here despite individuals with diabetes presenting as a higher risk group of patients compared to those without diabetes, participants with diabetes were less likely to receive high quality inpatient care. Importantly, we also show that, compared to participants without diabetes, they have a greater improvement in 1 year mortality conferred by high quality inpatient care. This improved longer-term survival was evident for all participants irrespective of their diabetic treatment regime. We suspect that one aspect of this disparity in quality-of-care benefit will be related to the rapidity of revascularisation, it is important to consider that participants with diabetes had a greater comorbidity burden and presented with more clinically adverse features of STEMI. Therefore, it is possible that these participants are susceptible to additional survival benefits from guideline directed medical therapy (GDMT). For example, participants with diabetes were more likely to develop severe LV dysfunction. Therefore, GDMT including β-blockers and ACE inhibitors, would confer a survival benefit in both STEMI and heart failure outcomes. Furthermore, our quality-of-care analysis indicates that participants with diabetes achieve lower rates of referral to cardiac rehabilitation services. Engagement with cardiac rehabilitation has been shown to lower mortality risk within AMI[27] and thus suboptimal referral for rehabilitation, in part, will be contributing to this excess mortality risk. We show that a considerable number of lives could be saved if participants with diabetes, receiving substandard care, received excellent care, which further highlights the importance of providing this cohort with excellent, guideline directed care.

To our knowledge, this study is the largest and first national analysis to report on up to 10-year mortality follow up data and to explore the relationship between the quality of inpatient care and long-term mortality outcomes in participants with STEMI with and without diabetes. Future research should aim to identify and address disparities in quality of care and review how to improve access to GDMT, timely invasive investigations and treatments. Improvements in these areas of care are likely to improve the long-term survival of this growing population.

4.1. Strengths

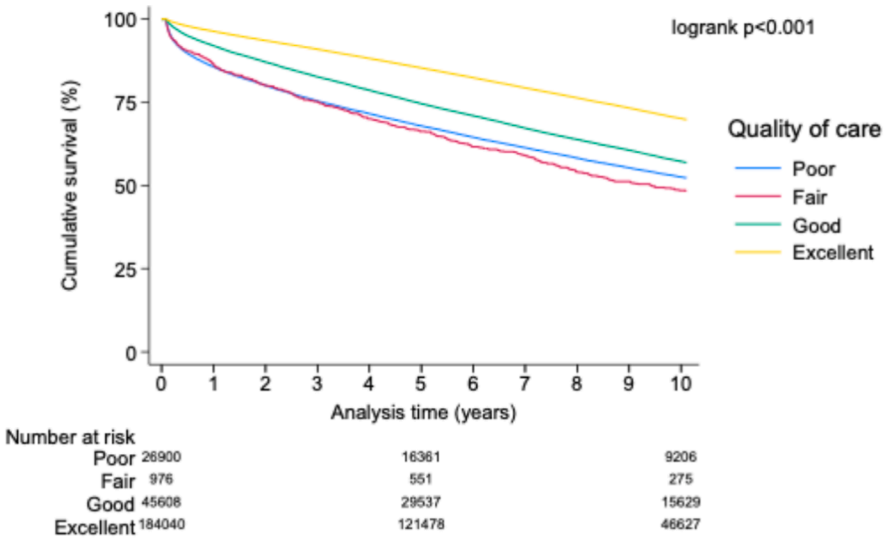
There are several strengths to this study. The MINAP registry collects robust data, with many recorded variables from all individuals presenting to hospitals with STEMI in the UK. Linking this with ONS data provides robust mortality data linkage. This allows for regional differences within the UK to be balanced out and thus our results are more likely to be representative of other publicly funded healthcare models globally. Our post-discharge mortality data, with a median duration of follow-up of 6.24 years gives us a long follow up period through which to assess mortality risks. Our follow up period also allows us to assess time weighed changes in mortality that does not include a period in which the COVID-19 pandemic occurred, wherein trends of mortality and morbidity were significantly altered.

4.2. Limitations

This study has several limitations comparable to other large national databases. Whilst MINAP collects many variables, it lacks data on frailty, treatment rationale, angiographic findings, and a comprehensive list of comorbidities. MINAP also has strict definitions for comorbidities; for example, CKD is defined as creatinine $>$ 200 micromol/L, preventing subclassification by kidney disease severity. Additionally, there is no external validation of data inputs.

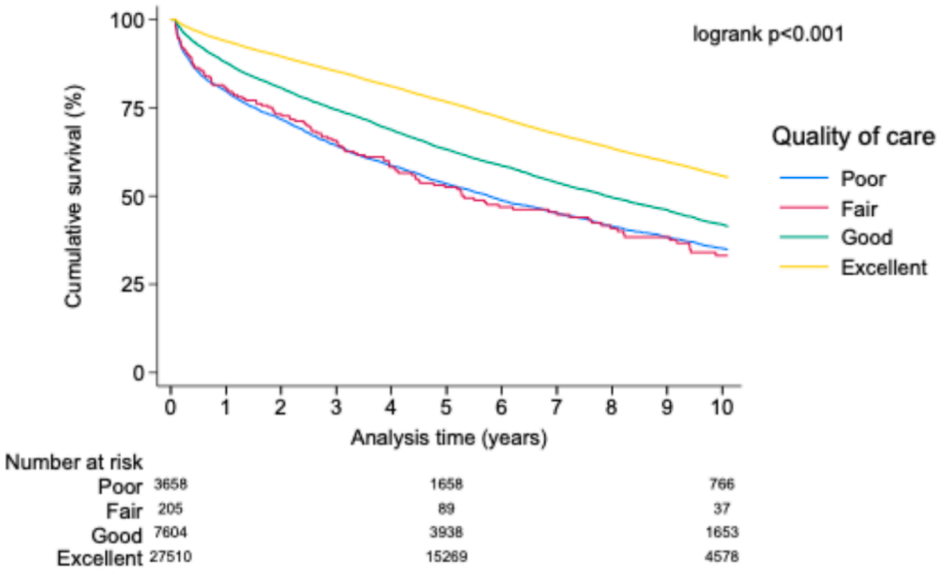
Data is collected at the point of STEMI diagnosis, without noting the initial diabetes diagnosis date. Thus, our diabetes cohort includes both participants with a historic and new diabetes diagnosis, with newly diagnosed individuals often marked as 'diet controlled.' This makes this subgroup heterogeneous, as some individuals will have not received prior diabetic advice. The MINAP registry does not collect data on individuals HbA1c, so we are unable to comment on their quality of glycaemic control. Neither does the MINAP registry record the tablet regime that participants in this category are using. This is particularly important to consider with the expanded and evolving role of SGLT2 inhibitors within cardiovascular disease[28]. For mortality outcomes related to treatment, we lack data on long-term medication adherence and cannot track individuals transitioning through different diabetic treatments over time. Importantly the MINAP registry does not capture

(I) All participants



Comparison to 'poor' care according to OBQI score:
Fair: HR 0.99 (0.68-1.44), p=0.951
Good: 0.81 (0.77-0.85), p<0.001
Excellent: 0.60 (0.58-0.63), p<0.001

(II) All participants with diabetes



Comparison to 'poor' care according to OBQI score:
Fair: HR 0.59 (0.29-1.19), p=0.140
Good: 0.80 (0.71-0.91), p<0.001
Excellent: 0.56 (0.50-0.64), p<0.001

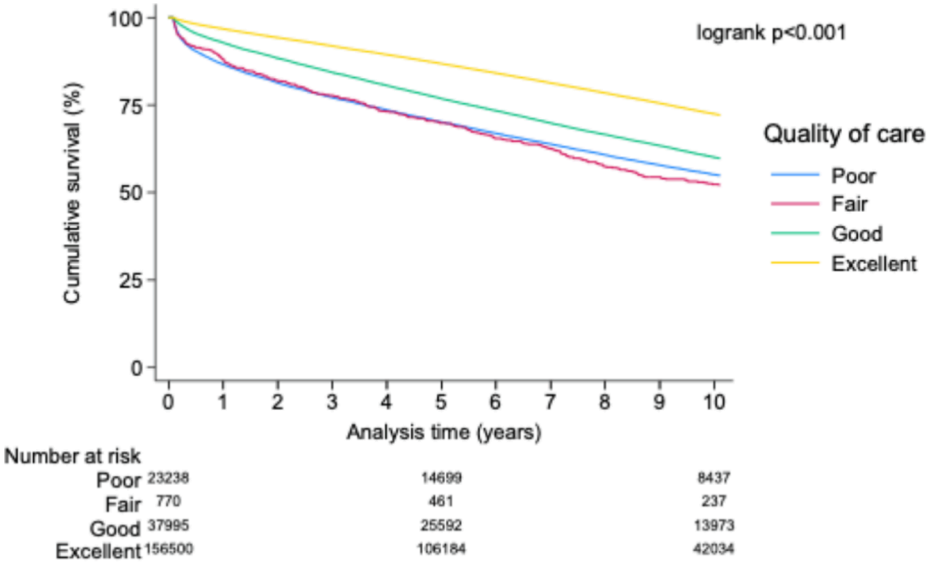
Fig. 3. Impact of inpatient quality of care according to Opportunity Based Quality Indicator score (OBQI) on clinical outcomes of individuals with diabetes mellitus. Results landmarked to exclude mortality within 30 days of admission to reflect aspects of OBQI score that are assessed on discharge.

information on diabetes subtypes and therefore we are not able to subcategorise individuals depending on if they have type 1 or type 2 diabetes mellitus.

Within our use of the OBQI score to assess quality of care, participants were excluded if medications were recorded as clinically contraindicated or not applicable. It is possible that participants had medications omitted appropriately but without clear clinical reasoning documented which would have negatively affected our assessment of their quality of care.

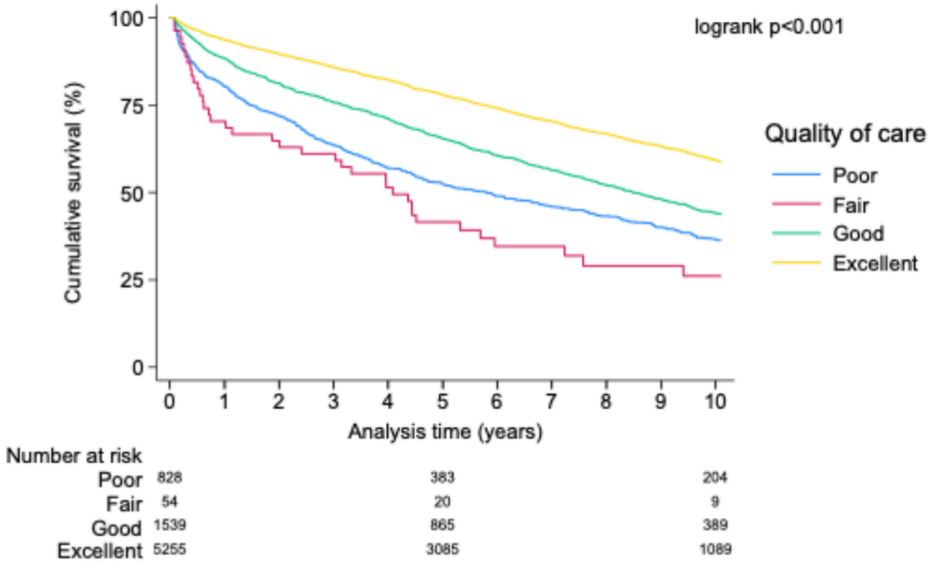
Although we present prospective data and our modelling adjusted for many important confounding variables, these observational data have potential for residual confounding and therefore there should be caution in making causal inferences.

(I) All participants without diabetes



Comparison to 'poor' care according to OBQI score:
Fair: HR 1.16 (0.75-1.81), p=0.508
Good: 0.81 (0.75-0.87), p<0.001
Excellent: 0.62 (0.58-0.67), p<0.001

(II) Diet treated participants with diabetes



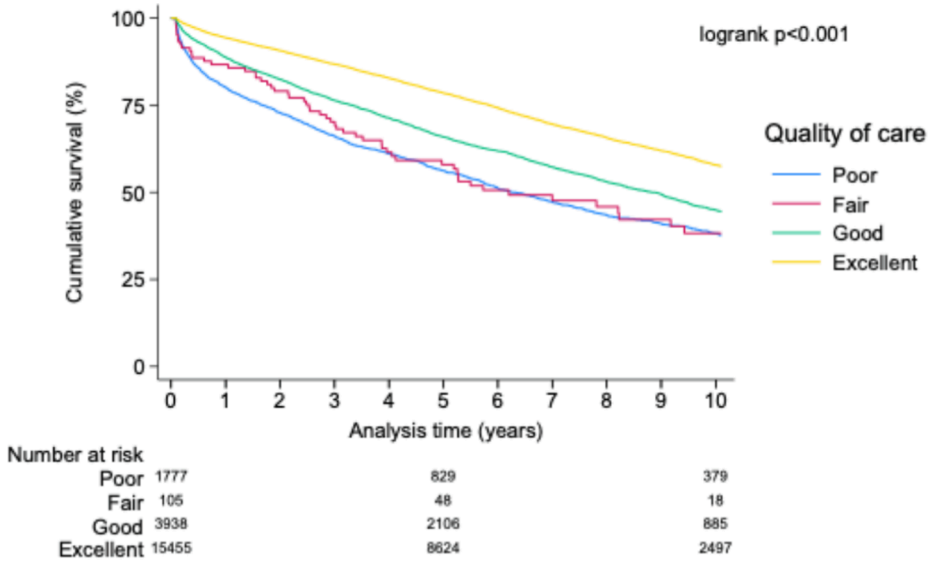
Comparison to 'poor' care according to OBQI score:
Fair: HR 0.47 (0.06-3.45), P=0.46
Good: 0.75 (0.58-0.98), P=0.038
Excellent: 0.50 (0.38-0.66), P<0.001

Fig. 3. (*continued*).

5. Conclusion

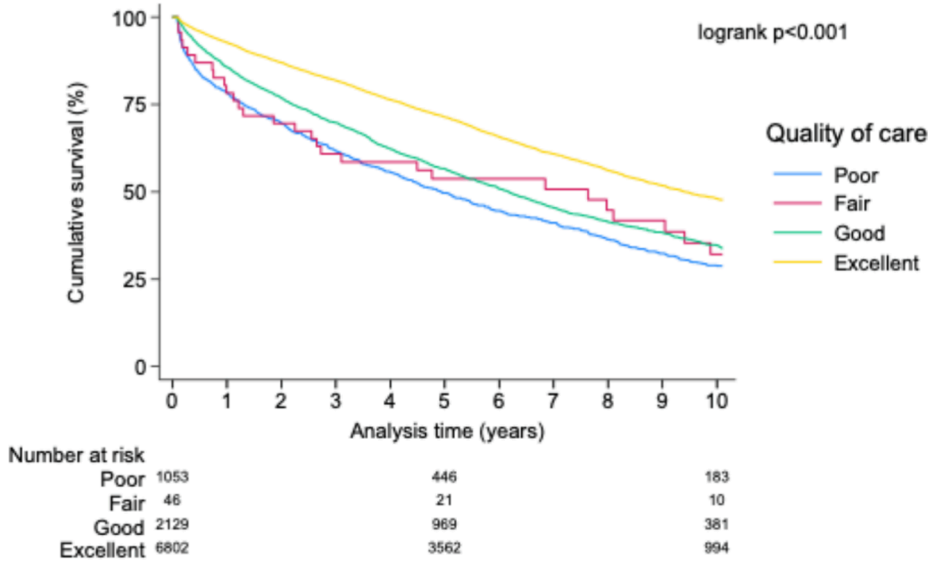
Our analysis reveals significant differences in the management of individuals with and without diabetes. Individuals with diabetes present as a higher risk group of patients with STEMI but receive lower quality inpatient care with less frequent and delayed invasive coronary angiography. They experience higher mortality risks at all time-points up to 10 years. Insulin-treated participants have the highest long-term mortality risk. There is considerable potential to save thousands of lives if participants with diabetes receive excellent inpatient care. The study underscores the importance of high-quality inpatient care in reducing long-term mortality for all individuals with diabetes.

(III) Tablet treated participants with diabetes



Comparison to 'poor' care according to OBQI score:
Fair: HR 0.65 (0.24-1.76), p=0.399
Good: 0.81 (0.67-0.97), p=0.025
Excellent: 0.58 (0.48-0.70), p<0.001

(IV) Insulin treated participants with diabetes



Comparison to 'poor' care according to OBQI score:
Fair: HR 0.67 (0.21-2.12), p=0.493
Good: 0.92 (0.74-1.13), p=0.421
Excellent: 0.67 (0.54-0.83), p<0.001

Fig. 3. (*continued*).

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7. Ethics

Secondary use of anonymised MINAP dataset for research purposes is authorised under NHS research governance arrangements and further supported under section 251 of NHS act 2006 (NIGB: ECC1-06(d)/2011), which allows researchers to use patient information collected within the dataset for medical research without patient consent. Therefore, formal ethical approval was not sought for this study.

CRediT authorship contribution statement

Andrew Cole: Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Nicholas Weight:** Writing – review & editing, Methodology, Formal analysis. **Harindra C. Wijeysundera:** Writing – review & editing. **Muhammad Rashid:** Writing – review & editing, Data curation. **Dahai Yu:** Writing – review & editing. **Emma L**

Healey: Writing – review & editing. **Nicholas WS Chew:** Writing – review & editing, Conceptualization. **Zbigniew Siudak:** Writing – review & editing. **Kamlesh Khunti:** Writing – review & editing. **Evangelos Kontopantelis:** Writing – review & editing, Formal analysis, Data curation. **Mamas A Mamas:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [KK has acted as a consultant, speaker or received grants for investigator-initiated studies for Astra Zeneca, Bayer, Novo Nordisk, Sanofi-Aventis, Servier, Lilly and Merck Sharp & Dohme, Boehringer Ingelheim, Oramed Pharmaceuticals, Pfizer, Roche, Daiichi-Sankyo, Applied Therapeutics, Embecta and Nestle Health Science].

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2025.112092.

Data availability

The data underlying this article were provided by the National Institute for Cardiovascular Outcomes Research (NICOR). Data will be shared on request to corresponding author with permission of NICOR.

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