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Impact of socioeconomic deprivation on mechanical thrombectomy outcomes after acute ischaemic stroke: findings from a London-based multicentre study

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ABSTRACT

Background Mechanical thrombectomy (MT) improves outcomes in patients who had an acute ischaemic stroke due to large vessel occlusion (LVO). However, socioeconomic status (SES) can influence recovery and prognosis. This study investigated the effect of SES, assessed via the Index of Multiple Deprivation (IMD), on MT outcomes in a multicentre London cohort.

Methods This retrospective study included patients with anterior circulation LVO treated with MT between 2021 and 2023 at three London hospitals. Patients were grouped into $IMD_{1–5}$ (more deprived) and $IMD_{6–10}$ (less deprived). Inverse probability weighting balanced baseline characteristics. Primary outcomes were 90-day functional independence (modified Rankin Scale (mRS) 0–2) and 90-day mRS shift. Secondary outcomes included recanalisation, early neurological changes, 90-day mortality, symptomatic intracerebral haemorrhage (sICH) and haemorrhagic transformation (HT). Subgroup analyses explored interactions between IMD and demographic or clinical factors. LASSO (Least Absolute Shrinkage and Selection Operator) regression identified predictors of functional independence, while receiver operating characteristic analysis evaluated IMD's predictive value.

Results Among 1219 patients with acute LVO ischemic stroke treated with MT, 533 (43.7%) were in $IMD_{1–5}$ and 686 (56.3%) in $IMD_{6–10}$. $IMD_{1–5}$ patients had lower odds of functional independence at 90 days (RR 0.79, 95% CI 0.70 to 0.90) and worse mRS shift (OR 1.29, 95% CI 1.06 to 1.58). They also had higher risks of sICH (RR 2.07, 95% CI 1.54 to 2.67) and HT (Risk Ratio 1.47, 95% CI 1.21 to 1.80). Subgroup analysis highlighted IMD's predictive importance in Asian or mixed ethnicity groups. A model incorporating IMD, age, sex, hypertension and National Institutes of Health Stroke Scale (area under the curve 0.656) demonstrated predictive accuracy for 90-day functional independence.

Conclusions Lower SES correlates with worse outcomes and higher complications post-MT, even within a universal healthcare system. Addressing SES disparities could improve stroke care equity.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous research has shown that socioeconomic status (SES) significantly impacts stroke outcomes, with lower SES associated with higher rates of functional impairment and poststroke complications. While SES disparities have been studied broadly in stroke populations, few studies specifically focus on patients undergoing mechanical thrombectomy (MT).

WHAT THIS STUDY ADDS

⇒ This study demonstrates that, even in a setting with universal healthcare, lower SES (measured by the Index of Multiple Deprivation) is associated with poorer functional recovery and a higher risk of complications, such as symptomatic intracerebral haemorrhage, following MT. Unlike previous studies, our findings emphasise that SES disparities persist in poststroke outcomes specifically among MT patients, highlighting SES as a significant determinant of both functional and safety outcomes in this advanced intervention.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings highlight the necessity of addressing SES-related barriers within stroke care, even in healthcare systems aiming for equity. Interventions aimed at supporting socioeconomically disadvantaged patients who had a stroke—such as enhanced rehabilitation support, better access to follow-up care and targeted health education—are essential to improve recovery outcomes. This study provides a basis for policy changes that prioritise SES as a factor in poststroke care strategies, encouraging further research into tailored support for low SES groups in MT outcomes.

INTRODUCTION

Stroke remains a leading cause of death and long-term disability worldwide, with ischaemic stroke constituting the majority of cases.[1] Advances in acute stroke care, particularly the advent of reperfusion therapies such as intravenous thrombolysis and mechanical thrombectomy (MT), have significantly improved outcomes in eligible patients. MT,

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in particular, has revolutionised the treatment of large vessel occlusion (LVO) strokes, offering the potential for substantial functional recovery when performed promptly.[2–5] However, the benefits of these therapies are not equally distributed across all populations, with socioeconomic status (SES) emerging as a key determinant of access and outcomes in stroke care.[6–8] SES encompasses multiple dimensions, including income, education, employment, housing and geographic access to healthcare services.[9] In the UK, the Index of Multiple Deprivation (IMD) integrates data from these domains, providing a robust measure of SES. Lower SES, as captured by lower IMD scores, has been associated with delayed access to acute therapies, reduced utilisation of MT and poorer poststroke outcomes.[6 10] The reasons for these disparities are multifactorial, including structural barriers, inequitable distribution of healthcare resources and differences in health literacy and comorbidities.[8] The effectiveness of MT in improving outcomes for patients who had an LVO stroke depends heavily on timely intervention, access to comprehensive stroke centres and subsequent rehabilitation.[11] Patients from deprived socioeconomic backgrounds often experience delays in seeking care, lower rates of hospital presentation within treatment windows and limited access to MT-capable centres.[6 7] Moreover, the interaction between SES and individual demographic and clinical characteristics, such as age, sex, ethnicity and comorbid conditions, may further exacerbate disparities in outcomes.

Despite growing evidence linking SES to stroke outcomes, there is limited understanding of how these factors interact in the context of advanced treatments such as MT. Additionally, the role of SES in modifying recovery trajectories for patients with different demographic or clinical profiles remains underexplored. This study seeks to examine the impact of SES, as measured by the IMD, on 90-day functional outcomes in a multicentre cohort of patients who experienced LVO acute ischaemic stroke treated with MT in the London metropolitan area. By analysing interactions between SES and key demographic and clinical variables, this work aims to identify vulnerable populations and inform strategies to improve equity in stroke care and outcomes, particularly in the era of MT.

METHODS

This is a multicentre observational, investigator-initiated, retrospective study investigating the impact of SES on outcomes of patients who had an acute ischaemic stroke consecutively treated with MT for anterior circulation LVO in three MT capable centres in the London metropolitan area (UK) (Charing Cross Hospital, Imperial College Healthcare NHS Trust; St George's University of London; University College London Hospitals, London) between 1 January 2021 and 31 December 2023 with local registries available.[9 12 13] Based on the patients' postcode of residence at the time of their stroke, we calculated the IMD 2019 to assess baseline SES for each individual (https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019?utm_) figure 1. The IMD is a composite measure that reflects relative deprivation at a small-area level, specifically lower layer super output areas (LSOAs), which typically encompass an average population of approximately 1500 individuals. This overall index aggregates 38 indicators across seven dimensions of deprivation, weighted as follows: income (22.5%), employment (22.5%), health and disability (13.5%), education, skills and training (13.5%), barriers to housing and services (9.3%), crime (9.3%) and living environment (9.3%). Each area is ranked from the most deprived to the least deprived, allowing for comparative analyses of socioeconomic conditions. The IMD is particularly useful for measuring changes over time, as the boundaries of lower LSOAs remain fixed, unlike electoral wards. The smaller average population size of LSOAs (approximately 1500 compared with around 6000 in electoral wards) contributes to increased population homogeneity and minimises the mixing of residents with varying levels of deprivation. In England, there are 32 482 LSOAs, each ranked in ascending order based on their deprivation scores. IMD scores range from 1 to 100, with higher scores indicating more deprived areas; for analytical purposes, these scores are often categorised into deciles with decile 1 representing the most deprived 10% of areas, while decile 10 the least deprived 10% of areas. For the purpose of this analysis, we compared outcomes of patients who had an acute ischaemic stroke undergoing MT divided into two subgroups: (1) deciles 1–5 representing the more deprived half of areas ($IMD_{1–5}$) and (2) decile 6–10 representing the less deprived half of areas ($IMD_{6–10}$).

Organisation of the London Stroke Network

This study draws on data from the three thrombectomy-capable hospitals within the London Stroke Network, which collectively serve a densely populated urban region of over 9 million people. These centres provide round-the-clock access to MT, either by receiving patients directly through a 'mothership' model or via transfer from affiliated primary stroke centres following initial treatment—referred to as the 'drip-and-ship' model.

Under the protocols of the London Stroke Network, patients identified as having signs of stroke—based on the Face, Arms, Speech, Time assessment conducted by paramedics on scene—are transported to the closest stroke centre equipped to provide thrombolysis. However, only designated thrombectomy centres are able to offer both thrombolysis and MT. If a patient at a primary stroke centre is assessed as a potential candidate for thrombectomy, they are transferred to a thrombectomy centre to receive further intervention. This decision-making process involves remote consultation through a telestroke system between the primary stroke centre and the on-call consultant at the thrombectomy site.

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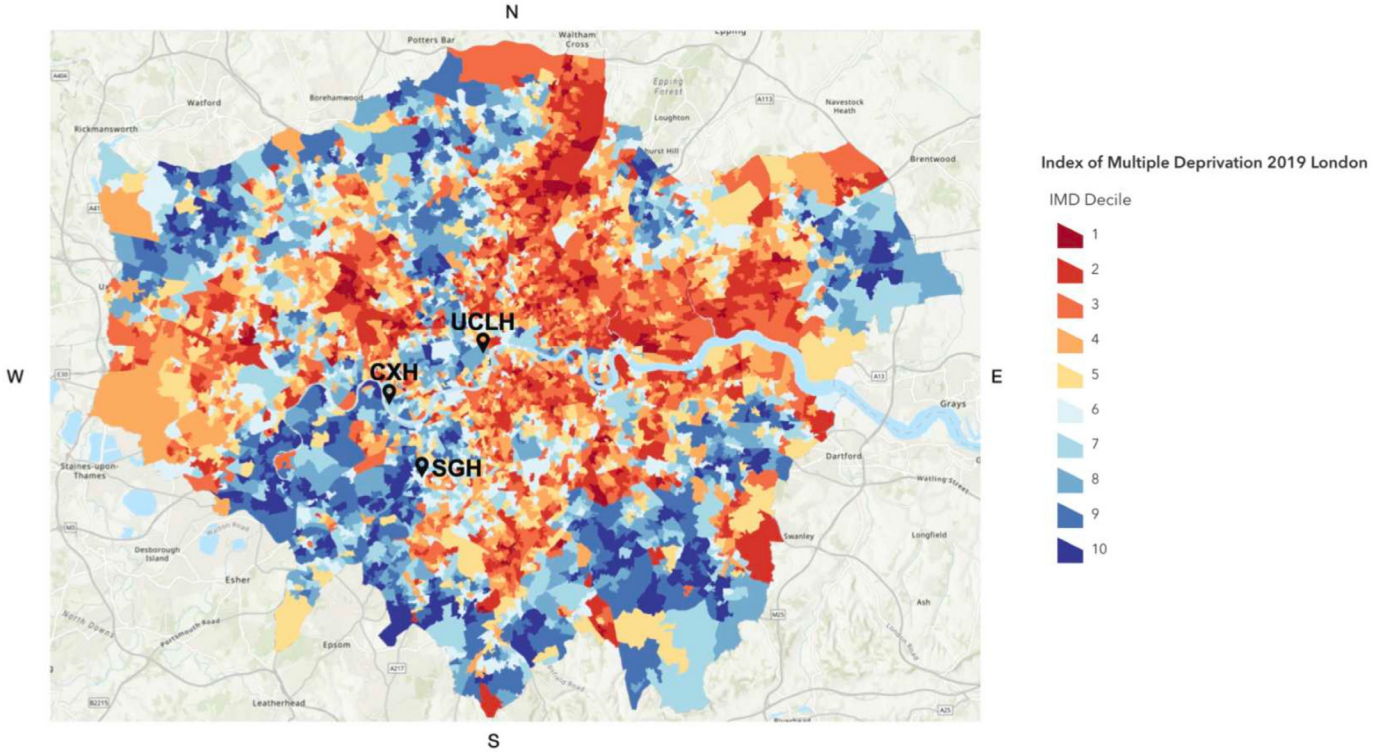


Figure 1 Index of Multiple Deprivation (IMD) 2019 across the London metropolitan area andthe three thrombectomy capable centres of the London Stroke network included in the study.N, North; W, West; E, East; S, South; CXH, Charing Cross Hospital, Imperial College Healthcare NHS Trust; SGH, St George's University of London; UCLH, University College London Hospitals.

Patients

Patients presenting with signs of acute stroke were assessed promptly in the hyperacute phase, using appropriate neuroimaging techniques such as CT and, when indicated, CT angiography to evaluate vascular status. Those who met the established inclusion criteria and had no contraindications were considered for acute recanalisation therapies. Individuals arriving within 4.5 hours of symptom onset were eligible for intravenous thrombolysis. MT was considered for patients who met specific clinical and radiological criteria: a prestroke modified Rankin Scale (mRS) Score of 0–2, a National Institutes of Health Stroke Scale (NIHSS) Score of 6 or higher (as agreed on by the multidisciplinary stroke and interventional radiology teams in line with current evidence) and the presence of an LVO in the anterior circulation. MT was initiated within 6 hours of stroke onset, or beyond this time window if patients qualified under the DAWN (DW or CTP Assessment with Clinical Mismatch in the Triage of Wake-Up and Late Presenting Strokes Undergoing Neurointervention with Trevo)

or DEFUSE 3 (The Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke)

eligibility criteria.[14 15] All patients received a comprehensive clinical evaluation at baseline.

Data collection

Information on established stroke risk factors was extracted from patients' medical records and included variables such as age, sex, ethnicity and cohabitation status. Cardiovascular risk profiles were documented as follows: a history of hypertension (defined as blood pressure readings consistently above 140/90 mm Hg on at least two occasions prior to the acute event or current use of antihypertensive medications), diabetes mellitus (diagnosed by a random plasma glucose>11.1 mmol/L, fasting glucose>7.0 mmol/L, HbA1c (Hemoglobin A1c) >48 mmol/mol or ongoing antidiabetic treatment) and hyperlipidemia (total cholesterol≥200 mg/dL, triglycerides≥140 mg/dL or use of lipid-lowering therapy). Alcohol consumption exceeding 14 units per week and current smoking status were also noted. Presence of atrial fibrillation (AF), either previously diagnosed or detected on admission, was recorded, along with a history of coronary artery disease, heart failure, prior ischaemic stroke or transient ischaemic attack (TIA) and previous intracranial haemorrhage. Stroke severity at presentation was assessed using the NIHSS Score. Functional status prior to stroke onset and at 90 days post stroke was measured using the mRS. Follow-up at 90 days was performed either in person at the thrombectomy-capable or referring stroke centre, or remotely through telemedicine. Data were also collected on the administration of intravenous thrombolysis, as well as prior use of antiplatelet or anticoagulant therapy. Key time metrics, including onset-to-door and onset-to-groin times, were prospectively recorded.

Study outcomes

The primary outcome was 90-day favourable mRS Score (0–2) after index event treated with MT and 90-day

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ordinal distribution of patients' mRS scores. Secondary outcomes included the rate of successful recanalisation assessed by applying the modified thrombolysis in cerebral infarction (mTICI) classification[16] (mRS 2b, 2c or 3 of recanalisation); 24 hours early neurological improvement, which was defined as a persistent decrease of 4 points or more in the NIHSS Score within 24 hours of admission; 24 hours early neurological deterioration, which was defined as a persistent increase of ≥4 points in the NIHSS Score within 24 hours of admission but not related to cerebral haemorrhage. Safety outcomes were: 90-day mortality; postprocedural haemorrhagic transformation (HT) defined on follow-up CT at 24 hours as any of the following: small petechiae along the margins of the infarct (haemorrhagic infarction (HI)-1) or as more confluent petechiae within the infarcted area but without space-occupying effect (HI-2), parenchymal haematoma (PH) was defined as haematoma in <30% of the infarcted area with some slight space-occupying effect (PH-1) or as dense haematoma in ≥30% of the infarcted area with substantial space-occupying effect or as any haemorrhagic lesion outside the infarcted area (PH-2); in the case of more than one haemorrhagic lesion on brain scan, the worst possible category was assumed; symptomatic intracerebral haemorrhage (sICH) as haemorrhage with a decline in neurological status (an increase of more than 4 points in the NIHSS).[17]

Statistical analysis

Descriptive categorical data were reported as numbers and proportions; descriptive continuous data were reported as means and SDs for normally distributed variables, or medians and IQRs for non-normally distributed variables. Demographic, clinical characteristics of the two groups ($IMD_{1–5}$ vs $IMD_{6–10}$) were compared using the χ^2 test for categorical variables. For continuous variables, t-tests for normally distributed data and Mann-Whitney U tests for non-normally distributed data were employed. P values were considered statistically significant at <0.05. To achieve balanced baseline characteristics between $IMD_{1–5}$ and $IMD_{6–10}$ patients who had a stroke, inverse probability weighting (IPW) was applied to create a pseudomatched cohort. Propensity scores were generated using a logistic regression model incorporating predefined baseline variables: age, sex, cohabitation status, ethnicity, risk factors (hypertension, diabetes, hyperlipidaemia, alcoholism, smoking status, prior TIA/ischaemic stroke, known AF, newly diagnosed AF, heart failure, coronary artery disease, previous intracranial haemorrhage), therapy on admission (oral anticoagulation, antiplatelet treatment), stroke severity (NIHSS at admission), pre-thrombectomy Alberta Stroke Scale Early CT Score, prehospital care, known onset, site of distal occlusion, procedural features (onset to door and groin time, administration of intravenous thrombolysis, type of anaesthesia, type of technique for distal thrombus thrombectomy, first pass successful, number of passes).

Propensity scores were then used to assign inverse probability weights to each patient. Standardised mean differences (SMD) were calculated to assess balance between groups, ensuring comparability of propensity score distributions. Stabilised weights were applied to reduce the impact of extreme values and improve model reliability. For the primary effectiveness outcomes, the risk ratio and risk difference with 95% CIs were calculated for the 90-day occurrence of favourable mRS scores between $IMD_{1–5}$ and $IMD_{6–10}$ groups. The shift in 90-day mRS scores was analysed using an ordinal generalised linear model (GLM), with results presented as ORs and 95% CIs. A proportional odds model (cumulative logit) was applied, given the ordinal nature of the mRS categories. For secondary effectiveness outcomes, risk ratios and differences were computed for postprocedural favourable mTICI scores, 24-hour early neurological improvement and 24-hour early neurological deterioration. Linear regression was used to compare changes in NIHSS scores from baseline, with results expressed as ORs and 95% CIs. Safety outcomes, including 90-day mortality, postprocedural HT and sICH, were analysed using risk differences and risk ratios with 95% CIs. All outcome analyses were conducted in the weighted population. A logistic regression model with restricted cubic splines was employed to assess the continuous relationship between IMD and the probability of achieving a 90-day mRS Score of 0–2 in the weighted population. Knots for the splines were positioned at the 10th, 50th and 90th percentiles of IMD. The median IMD served as the reference point, with ORs estimated relative to this value. Log ORs were exponentiated to derive ORs, and 95% CIs were calculated using SEs. The OR curve was examined to determine a clinical cut-off for IMD, identifying the value where OR approached 1, suggesting no significant impact on risk.

Subgroup analysis of the primary outcome (90-day mRS 0–2) was conducted for predefined categories, including age (≤75 or >75 years), prestroke model of care, ethnicity, cohabitation status, sex, known onset, use of intravenous thrombolysis, diabetes, hypertension, heart failure and coronary artery disease. A GLM model incorporating IMD, subgroup variables and interaction terms was used to assess heterogeneity in IMD effects across subgroups, with interaction p values reported. Given the exploratory nature of the study and absence of predefined assumptions for IPW analysis, no formal sample size calculation was performed. LASSO (Least Absolute Shrinkage and Selection Operator) regression analysis was conducted to identify variables most strongly associated with favourable functional outcomes at 90 days in the weighted population. The predictive value of these factors, alone or in combination with IMD, was assessed using the area under the receiver operating characteristic curve (AUC-ROC). ROC curves were compared using the DeLong test. All statistical analyses were performed using R software, V.4.2. Statistical significance was defined as p<0.05.

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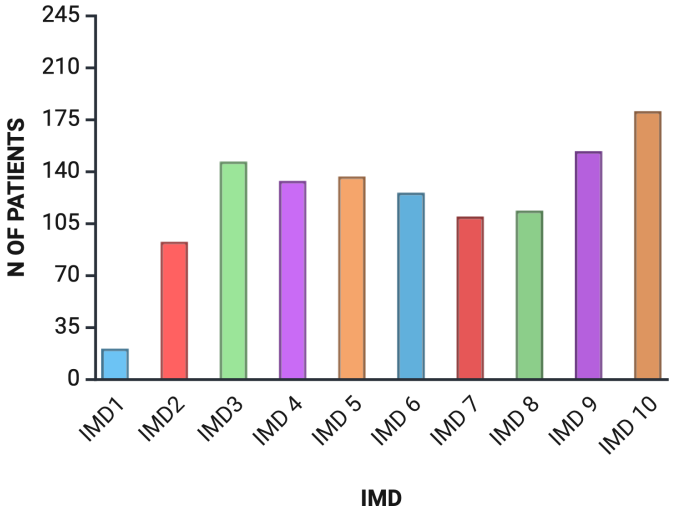


Figure 2 Distribution of the Index of Multiple Deprivation (IMD) in the study population.

RESULTS

Overall, our analysis included 1219 patients who had an acute ischaemic stroke undergoing MT due to anterior circulation LVO, of whom 533 (43.7%) were $IMD_{1–5}$, while 686 (56.3%) were $IMD_{6–10}$ (online supplemental figure 1, study algorithm). Figure 2 reports the distribution of patients who had an acute stroke undergoing MT according to their IMD values. Baseline characteristics of the two groups of patients are reported in table 1. Patients in the $IMD_{1–5}$ group were significantly younger (p<0.001), had more diabetes (p=0.036) and more frequently were smokers (p<0.001) compared with those of the $IMD_{6–10}$ group. The two groups differed significantly in terms of ethnicity distribution (p<0.001). The χ^2 test of independence revealed no statistically significant association between the ethnicity distribution and the three MT centres (p=0.776) (online supplemental table 1). In the $IMD_{1–5}$ group, 38.6% were directly admitted to a comprehensive stroke centre for consideration for MT compared with 57% of the $IMD_{6–10}$ cohort (p<0.001). A higher proportion of patients in the $IMD_{6–10}$ cohort had a known stroke onset compared with the $IMD_{1–5}$ counterpart (p=0.002). There was no significant difference in occlusion sites, thrombolysis and MT processing times and MT methods. Online supplemental tables 2 and 3 report treatment metrics across the three MT centres.

Weighted and unweighted baseline characteristics are summarised in table 1. Overall, a satisfactory balance was achieved for all baseline variables which showed a SMD of propensity scores below 0.20.[18] Graphical representations of propensity scores and covariate balance distributions confirmed the overall quality of the matching process (online supplemental figure 2). Table 2 reports the outcome comparison between $IMD_{1–5}$ and $IMD_{6–10}$ patients after IPW. $IMD_{1–5}$ patients showed a significantly lower rate of 90-day favourable outcome (mRS 0–2) compared with $IMD_{6–10}$ patients (risk ratio 0.79 (95% CI 0.70 to 0.90); p<0.001) (risk difference −10.96 (−16.58 to −5.35); p<0.001). The 90-day mRS shift analysis documented with higher mRS in $IMD_{1–5}$ patients compared with $IMD_{6–10}$ patients treated with MT for anterior circulation LVO (OR 1.29 95% CI 1.06 to 1.58; p<0.001) (figure 3). There were significant differences in the risk of HT post MT (ratio 1.47 (95% CI 1.21 to 1.80); p<0.001) and sICH (2.07 (95% CI 1.54 to 2.67); p<0.001). We found no significant differences in successful reperfusion rates (risk ratio 1.04 (95% CI 1.00 to 1.08); p=0.064), 24-hour early neurological improvement (risk ratio 0.91 (95% CI 0.82 to 1.00); p=0.058), 24-hour early neurological deterioration (risk ratio 1.19 (95% CI 0.81 to 1.76); p=0.380) and 90-day mortality (risk ratio 0.91 (95% CI 0.70 to 1.19); p=0.498).

The value–response relationship between IMD and 90-day mRS 0–2 in the weighted cohort of patients who had an acute ischaemic stroke undergoing MT due to anterior circulation LVO is shown in figure 4. A non-linear value–response relationship was found between IMD and 90-day mRS 0–2 (p for adjusted non-linear=0.025). This model suggests that the risk of 90-day mRS 0–2 increases with increasing values of IMD.

Results of subgroup analysis for the 90-day mRS (0–2) outcome in the weighted cohort are presented in table 3. We observed a significantly lower rate of favourable 90-day mRS Score (0–2) in $IMD_{1–5}$ patients who were Asian or Asian British (RD −23% (95% CI −39% to −8%); p=0.006) or mixed ethnicity (RD −24% (95% CI −37% to −9%); p=0.002), female (RD −23% (−14% CI −22% to −6%); p<0.001), patients with no history of diabetes (RD −10% (95% CI −16% to −4%); p=0.001), with no history of hypertension (RD −9% (95% CI −17% to −7%); p=0.033), with no history of heart failure (RD −11% (95% CI −17% to −6%); p<0.001) and with no history of coronary artery disease (RD −12% (95% CI −18% to −6%); p<0.001).

A LASSO regression analysis was conducted to identify the variables most strongly associated with favourable functional outcomes at 90 days, in the weighted population. The values of the LASSO coefficients for each of the included variables after variation of the regularisation parameter lambda are shown in online supplemental figure 3. The plot shows how the relative importance of each variable changes at increasing the model size. At optimal model size (best lambda value determined by cross-validation +1 SE), the variables which were most associated with the favourable functional outcomes at 90 days were age, sex, hypertension, use of intravenous thrombolysis and NIHSS Score on admission. The coefficient estimates relative to the optimal model size are reported in online supplemental table 4.

Then, using the ROC curves from the logistic regression analysis, we identified the predictive accuracy for favourable functional outcomes at 90 days of two binomial logistic regression models (figure 5). The first model included age, sex, hypertension, use of intravenous thrombolysis and NIHSS Score on admission. The second model included the same variables as the model above, with the addition of IMD. The ROC curves showed

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Table 1 Baseline characteristics of $IMD_{1–5}$ versus $IMD_{6–10}$ patients

	Overall population (n=1219)	$IMD_{1–5}$ (n=533)	$IMD_{6–10}$ (n=686)	P value	SMD unweighted*	SMD weighted*
Demographics						
Age, median (IQR)	70 (58–79)	66 (56–77)	74 (61–70)	**<0.001**	0.331	0.019
Female, n (%)	584 (47.9)	261 (49)	323 (47.1)	0.568	0.014	0.001
Cohabitation status, n (%)						
Living alone	261 (21.4)	123 (23.1)	138 (20.1)	0.800	0.034	0.006
Living with someone else	958 (78.6)	410 (76.9)	548 (79.8)			
Ethnicity, n (%)						
Asian or Asian British	150 (12.3)	79 (14.8)	71 (10.3)	**<0.001**	0.147	0.005
Black	49 (4)	36 (6.8)	13 (1.9)			
Mixed	230 (18.9)	67 (12.6)	163 (23.8)			
White	496 (40.8)	204 (38.3)	292 (42.6)			
Other	294 (24)	147 (27.5)	147 (21.4)			
Prestroke risk factors						
Hypertension, n (%)	678 (55.6)	301 (56.5)	377 (55)	0.638	0.011	0.008
Hypercholesterolemia, n (%)	356 (29.2)	156 (29.3)	200 (29.2)	1.0	0.001	0.005
Diabetes mellitus, n (%)	223 (18.3)	112 (21.0)	111 (16.2)	**0.036**	0.047	0.001
Alcoholism, n (%)	122 (10)	60 (11.3)	62 (9.0)	0.236	0.022	0.003
Current smoking, n (%)	291 (23.9)	157 (29.5)	134 (19.5)	**<0.001**	0.099	0.001
Previous TIA/ischaemic stroke, n (%)	193 (15.8)	83 (15.6)	110 (16.0)	0.888	0.005	0.003
Known atrial fibrillation, n (%)	356 (29.2)	154 (28.9)	202 (29.4)	0.883	0.007	0.005
AFDAS, n (%)	182 (14.9)	72 (13.5)	110 (16)	0.251	0.025	0.002
Heart failure, n (%)	106 (8.7)	47 (8.8)	59 (8.6)	0.975	0.002	0.001
Coronary artery disease, n (%)	197 (16.2)	77 (14.4)	120 (17.5)	0.175	0.031	0.001
Previous ICH, n (%)	8 (0.7)	2 (0.4)	6 (0.9)	0.475	0.001	0.001
Therapy on admission, n (%)						
Oral anticoagulation, n (%)	185 (15.2)	92 (17.3)	93 (13.6)	0.088	0.037	0.002
Antiplatelet treatment, n (%)	194 (15.9)	75 (14.1)	119 (17.3)	0.141	0.033	0.003
NIHSS on admission, median (IQR)	16 (11–21)	16 (11–21)	16 (11–21)	0.686	0.011	0.016
ASPECT Score on admission, median (IQR)	9 (9–10)	9 (9–10)	9 (9–10)	0.612	0.056	0.003
Procedural features, n (%)						
Prehospital care, n (%)						
Mothership	597 (49)	206 (38.6)	391 (57)	**<0.001**	0.185	0.001
Drip-and-ship	622 (51)	327 (61.4)	295 (43)			
Known stroke onset, n (%)	893 (73.3)	367 (68.9)	526 (76.7)	**0.002**	0.077	0.001
Location of large vessel occlusion, n (%)						
Distal ICA	122 (10)	54 (10.1)	68 (10)	0.064	0.031	0.005
M1	702 (57.6)	298 (55.9)	404 (58.9)			
M2	169 (13.9)	82 (15.4)	87 (12.7)			
Tandem	226 (18.5)	127 (18.6)	99 (14.4)			
Intravenous thrombolysis, n (%)	652 (53.5)	279 (52.3)	373 (54.4)	0.518	0.020	0.002
Onset to door time (min), median (IQR)	207 (100–304)	218.5 (10.2.3–302)	196.9 (99.5–30.8.5)	0.193	0.035	0.015
Onset to groin time (min), median (IQR)	308 (231–400)	312.9 (240.5–401.5)	299 (224–400)	0.219	0.033	0.008

Continued

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Table 1 Continued

	Overall population (n=1219)	$IMD_{1–5}$ (n=533)	$IMD_{6–10}$ (n=686)	P value	SMD unweighted*	SMD weighted*
Type of anaesthesia, n (%)						
General	1063 (87.2)	458 (85.9)	605 (88.2)	0.277	0.022	0.001
Local	156 (12.8)	75 (14.1)	81 (11.8)			
First pass successful, n (%)	161 (13.2)	71 (13.3)	90 (13.1)	1.0	0.001	0.003
First pass technique used, n (%)						
Aspiration	666 (54.6)	298 (55.9)	368 (53.6)	0.465	0.020	0.005
Stent retriever	553 (45.4)	235 (44.1)	318 (46.4)			
Number of passes, n (%)	2 (1–3)	2 (1–3)	2 (1–3)	0.189	0.053	0.007

Statistically significant p values (<0.05) are reported in bold.
*A standardise difference (of means) <0.200 indicates that groups are well balanced.
AFDAS, atrial fibrillation detected after stroke; ASPECT, Alberta Stroke Scale Early CT; ICA, internal carotid artery; ICH, intracerebral haemorrhage; NIHSS, National Institutes of Health Stroke Scale; TIA, transient ischaemic attack.

an AUC of 0.635 (95% CI 0.604 to 0.666) for the model without IMD and 0.656 (95% CI 0.625 to 0.686) for the model with IMD. DeLong's test for comparing correlated ROC curves revealed a statistically significant difference between the two models (Z=−2.5263, p value=0.012), with a 95% CI for the AUC difference of −0.037 to −0.005. To evaluate the independent predictive value of IMD for our cohort of patients undergoing MT, we calculated the ROC curve using IMD as the sole predictor variable. The AUC for this analysis was 0.567 (95% CI 0.536 to 0.599) (figure 5).

DISCUSSION

Our multicentre study based in the London metropolitan area provides a comprehensive evaluation of SES as a determinant factor of outcomes in a large cohort of patients who had an acute ischaemic stroke undergoing MT. Our analysis indicates that SES, measured using the IMD, significantly influences both post-MT functional and safety outcomes, underscoring the impact of socioeconomic disparities on poststroke recovery. Specifically, we showed that patients who had a stroke from more deprived areas ($IMD_{1–5}$) exhibited poorer 90-day functional outcomes, increased risk of any HT following MT for acute ischaemic stroke due to LVO when compared with those from the less deprived half of areas ($IMD_{6–10}$).

Our findings align with existing literature that associated lower SES indicators with poorer functional outcomes after an acute stroke.[6] Indeed, previous reviews indicated that education, income, occupation, health insurance and area deprivation, as measures of SES, are associated with worse functional outcomes after acute ischaemic stroke.[7 8] However, most of these previous studies primarily examined general stroke populations, while only a few studies focused on patients undergoing MT. Indeed, Chen *et al* examined the impact of socioeconomic deprivation on functional outcomes after stroke using data from the South London Stroke Register of 1995 to 2011[19] and found that lower SES was significantly associated with poorer recovery at both 3 months and 3 years post stroke. In contrast to our study, the authors included a broader stroke population and did not address MT outcomes. Salwi *et al* conducted an observational study of 328 consecutive patients treated with MT at one US comprehensive stroke centre from 2012 to 2018.[20] The authors used a composite neighbourhood socioeconomic score, and based on this score, patients were divided into low, middle and high SES tertiles. The results of this study indicated that patients in the higher SES tertile were more likely to be functionally dependent at 90 days after MT. However, after adjusting for variance in race and severity of stroke, the differences in clinical outcomes were not significant. Subsequently, Hoefnagel *et al* retrospectively analysed 125 consecutive patients who had an acute stroke presenting for MT at a comprehensive stroke centre serving patients with high levels of socioeconomic deprivation.[21] The authors concluded that socioeconomic deprivation was not a factor significantly associated with outcomes after MT. While previous studies have reported mixed findings regarding the impact of SES on stroke outcomes, these discrepancies may stem from differences in study designs, patient populations and healthcare contexts. For instance, studies conducted in non-universal healthcare systems may reflect greater disparities in access to acute interventions, while our analysis in a universal healthcare setting underscores the persistence of SES-related disparities even when access to treatment is theoretically equitable. Additionally, variations in how SES is measured and accounted for could contribute to differing results. By focusing on patients undergoing MT, our study provides a unique perspective that highlights the influence of SES on both functional and safety outcomes in this advanced intervention.

Another significant finding of our analysis is the impact of SES on safety outcomes, such as sICH and HT after MT. This is in line with previous studies that found that lower

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Table 2 Outcome comparisons in the weighted population: $IMD_{1–5}$ versus $IMD_{6–10}$ patients

	Overall population (n=1219)	$IMD_{1–5}$ (n=533)	$IMD_{6–10}$ (n=686)	Statistical metric	Treatment difference (95% CI)	P value
Primary effectiveness outcomes						
90-day favourable mRS Score (0–2), n (%)	590 (48.4)	224 (42)	366 (53.4)	Risk ratio	0.79 (0.70 to 0.90)	**<0.001**
				Risk difference (%)	−10.96 (−16.58 to −5.35)	**<0.001**
90-day mRS Score distribution						
No symptoms (score of 0), n (%)	55 (4.5)	24 (4.5)	31 (4.5)	OR	1.29 (1.06 to 1.58)	**<0.001**
Symptoms without any disability (score of 1), n (%)	217 (17.8)	81 (15.2)	136 (19.8)			
Symptoms with mild disability (score of 2), n (%)	318 (26.1)	117 (22)	201 (29.3)			
Symptoms with mild-to-moderate disability (score of 3), n (%)	156 (12.8)	80 (15)	76 (11.1)			
Symptoms with moderate-to-severe disability (score of 4), n (%)	144 (11.8)	86 (16.1)	58 (8.5)			
Symptoms with severe disability (score of 5), n (%)	139 (11.4)	63 (11.8)	76 (11.1)			
Death (score of 6), n (%)	190 (15.5)	82 (15.4)	108 (15.8)			
Secondary effectiveness outcomes						
Postprocedural favourable TICI Score, n (%)	1093 (89.7)	489 (91.7)	604 (88.0)	Risk ratio	1.04 (1.00 to 1.08)	0.064
				Risk difference (%)	3.73 (0.36 to 7.10)	0.057
24-hour early neurological improvement, n (%)	681 (55.8)	282 (52.7)	399 (58.2)	Risk ratio	0.91 (0.82 to 1.00)	0.058
				Risk difference (%)	−5.44 (−11.06 to 0.18)	0.063
24-hour early neurological deterioration, n (%)	112 (9.2)	54 (10.1)	58 (8.5)	Risk ratio	1.19 (0.81 to 1.76)	0.380
				Risk difference (%)	1.46 (−1.82 to 4.74)	0.422
Safety outcomes						
90-day death, n (%)	190 (15.6)	82 (15.4)	108 (15.8)	Risk ratio	0.91 (0.70 to 1.19)	0.498
				Risk difference (%)	−1.55 (−6.02 to 2.92)	0.517
Postprocedural HT, n (%)	296 (24.3)	158 (29.6)	138 (20.1)	Risk ratio	1.47 (1.21 to 1.80)	**<0.001**
				Risk difference (%)	9.53 (4.62 to 14.43)	**<0.001**
Symptomatic ICH, n (%)	275 (22.6)	158 (29.6)	117 (17.1)	Risk ratio	2.07 (1.54 to 2.67)	**<0.001**
				Risk difference (%)	12.84 (8.05 to 17.63)	**<0.001**

Statistically significant p values (<0.05) are reported in bold.
HT, haemorrhagic transformation; ICH, intracerebral haemorrhage; mRS, modified Rankin Scale; TICI, thrombolysis in cerebral infarction.

SES was associated with increased risk of complications postacute stroke due to underlying health disparities, such as higher incidence of risk factors and potentially lower adherence to poststroke care guidelines.[1] Our results support this association, showing a significantly higher rate of sICH and HT after MT in the $IMD_{1–5}$ cohort, reinforcing the importance of SES in the comprehensive evaluation of stroke care.

Our subgroup analysis in the weighted cohort provided critical insights into the differential impact of socioeconomic deprivation on post-thrombectomy functional recovery. These findings underscore the multifactorial nature of disparities in stroke outcomes and highlight specific subgroups that may require targeted interventions. The significantly lower rates of favourable 90-day outcomes among Asian or Asian British and mixed-ethnicity patients within the $IMD_{1–5}$ group are indicative of the intersectional challenges faced by socioeconomically deprived minority populations. These results align with the existing literature suggesting that individuals from minority ethnic backgrounds often encounter additional barriers to optimal stroke care, including delayed access to treatment, cultural and linguistic barriers and potential biases within healthcare systems.[22–24] Despite the theoretically equitable access provided by the universal healthcare system in the UK, these findings suggest

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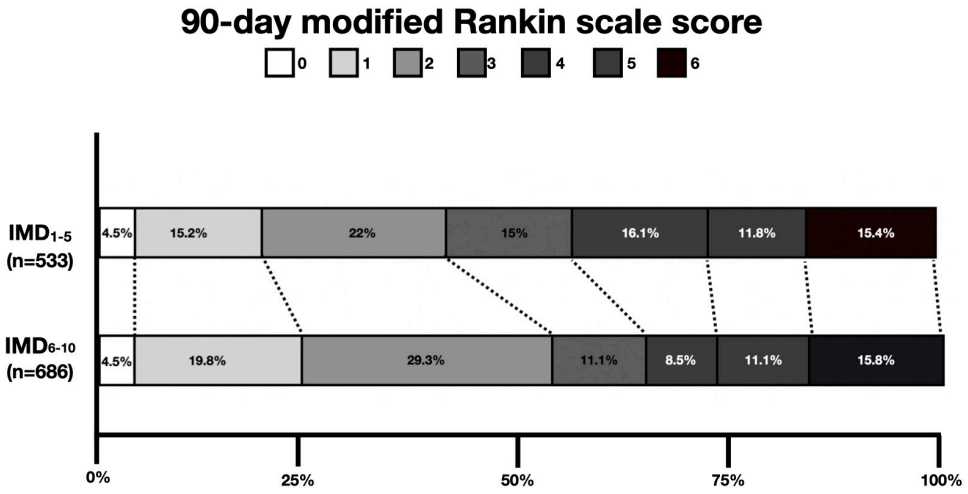


Figure 3 Distribution of modified Rankin Scale scores at 90 days in Index of Multiple Deprivation (IMD)$_{1–5}$ and IMD$_{6–10}$ patients who had an acute ischaemic stroke treated with mechanical thrombectomy.

that structural inequities persist and necessitate tailored approaches, such as culturally responsive rehabilitation programmes and targeted outreach to underserved communities.[23] Moreover, we observed disparity among female patients in the IMD$_{1–5}$ cohort, who demonstrated significantly worse outcomes compared with their male counterparts. Prior evidence has identified sex-related differences in stroke recovery, with women often experiencing worse functional outcomes due to biological, social and systemic factors.[25–27] These include differences in vascular risk profiles, a higher prevalence of poststroke disability and limited access to poststroke rehabilitation resources. This finding emphasises the importance of integrating sex-specific strategies into poststroke care to address these inequities effectively. Interestingly, patients without a history of diabetes, hypertension, heart failure or coronary artery disease in the IMD$_{1–5}$ group also exhibited worse functional outcomes. While this finding may seem counterintuitive, it could reflect lower baseline engagement with healthcare services among these individuals, leading to delays in diagnosis and management of other risk factors. It may also highlight the broader systemic challenges faced by socioeconomically deprived populations, including reduced health literacy and limited access to preventive care. Our analysis highlighted the pervasive nature of SES-related disparities in stroke recovery, even in a well-resourced healthcare setting such as London. Addressing these disparities requires a multifaceted approach that incorporates both systemic and individualised interventions. Potential strategies include enhanced access to multidisciplinary rehabilitation services, improved coordination of postdischarge care and policy initiatives aimed at reducing socioeconomic barriers to recovery.

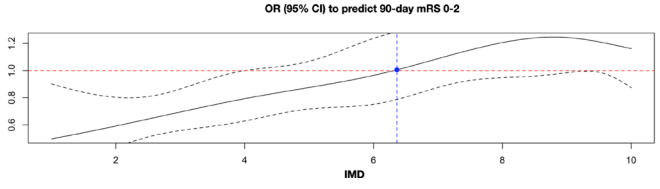


Figure 4 Restricted cubic spline models for risk of 90-day modified Rankin Scale (mRS) 0–2 in relation to Index of Multiple Deprivation (IMD). The OR is represented by the solid line and the 95% CI by the dotted lines.

Various mechanisms have been proposed to elucidate the association between low SES and poorer functional outcomes following a stroke worldwide. First, socioeconomic disadvantage may constrain access to high-quality medical care and rehabilitation services.[28] Evidence suggests that individuals with greater financial resources are more likely to engage in postdischarge rehabilitation, which is critical for optimal recovery.[29 30] Additionally, community-dwelling patients with lower levels of education typically receive less support from allied health services compared with those with higher educational attainment. However, these may be less likely an issue in the UK of universal healthcare. Our study confirmed that although patients who had a stroke from more deprived areas are more likely to arrive in MT centres via the drip-and-ship model, there was no significant delay from stroke onset to groin puncture time. Third, education serves as a fundamental determinant of health, fostering skills such as problem-solving and self-efficacy, which can enhance job stability, income and overall financial security.[31 32] These competencies may also be beneficial for managing health proactively, compliance with stroke prevention and rehabilitation and optimising recovery post stroke. Furthermore, individuals from lower SES backgrounds are at a higher risk of comorbid conditions and cardiovascular risk factors, such as hypertension, dyslipidaemia, diabetes and smoking, which can increase the MT complication rates, complicate recovery trajectories and exacerbate functional impairments following a stroke.[33 34] At last, individuals with lower SES may encounter more substantial challenges in adapting to physical limitations post stroke and may lack essential resources—such as home modifications and assistance with activities of

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Table 3 Subgroup analysis in the weighted cohort per outcome of 90-day mRS 0–2

	Patients (n)	Patients with 90-day mRS 0–2, n (%)		Risk difference* (%) (95% CI)	P value interaction
		$IMD_{1–5}$	$IMD_{6–10}$		
Age, years					
<75	743	174/373 (46.6)	219/370 (59.2)	−12 (−19 to 5)	**<0.001**
≥75	476	52/161 (32.3)	146/315 (46.3)	−14 (−23 to −5)	**0.003**
Prestroke model of care					
Mothership	597	86/206 (41.7)	204/391 (52.2)	−10 (−18 to 2)	**0.015**
Drip-and-ship	622	140/327 (42.8)	161/295 (54.6)	−12 (−19 to −4)	**0.003**
Ethnicity					
Asian or Asian British	150	28/79 (35.4)	42/71 (59.2)	−23 (−39 to −8)	**0.006**
Black	49	11/36 (30.6)	8/13 (61.5)	−31 (−71 to 3)	0.205
Mixed	230	24/67 (35.8)	97/163 (59.5)	−24 (−37 to −9)	**0.002**
White	496	93/204 (45.6)	146/292 (50)	−4 (−13 to 5)	0.381
Other	294	69/147 (46.9)	73/147 (49.7)	−3 (−14 to 9)	0.726
Cohabitation status					
Living alone	261	83/123 (67.5)	114/138 (82.6)	−15 (−25 to −5)	**0.004**
Living with someone else	958	140/410 (34.1)	252/548 (46)	−12 (−17 to −6)	**0.001**
Sex					
Female	584	93/261 (35.6)	163/323 (50.5)	−15 (−22 to −6)	**<0.001**
Male	635	122/272 (45)	202/363 (55.6)	−11 (−15 to −4)	0.064
Known onset					
Yes	893	157/367 (42.8)	279/526 (53)	−10 (−17 to −4)	**0.002**
Unknown	326	69/166 (41.6)	86/160 (53.8)	−12 (−23 to −2)	**0.022**
Intravenous thrombolysis					
No	567	96/254 (37.8)	149/313 (47.6)	−10 (−18 to −2)	**0.017**
Yes	652	130/279 (46.6)	216/373 (57.9)	−11 (−19 to −4)	**0.003**
Diabetes					
No	996	187/421 (44.4)	313/575 (54.4)	−10 (−16 to −4)	**0.001**
Yes	223	39/112 (34.8)	52/111 (46.8)	−12 (−24 to −7)	0.068
Hypertension					
No	541	116/232 (50)	181/309 (58.6)	−9 (−17 to −7)	**0.033**
Yes	678	110/301 (36.5)	184/377 (48.8)	−12 (−19 to −5)	**0.002**
Heart failure					
No	1113	208/486 (42.8)	341/627 (54.4)	−12 (−17 to −6)	**<0.001**
Yes	106	18/47 (38.3)	24/59 (40.7)	−2 (−21 to −16)	0.803
Coronary artery disease					
No	1022	190/456 (41.7)	304/566 (53.7)	−12 (−18 to −6)	**<0.001**
Yes	197	36/77 (46.7)	61/120 (51.2)	−4 (−18 to −10)	0.576

*$p < 0.05$
IMD, Index of Multiple Deprivation; mRS, modified Rankin Scale.

daily living—that are critical for mitigating the impact of stroke-related disabilities.[35 36] Socioeconomically disadvantaged patients may face barriers such as limited access to rehabilitation services, lower health literacy and inadequate social support, which can adversely impact functional outcomes. Addressing these downstream factors is essential for improving equity in stroke care and ensuring that all patients derive maximum benefit from advanced interventions such as MT. These multifaceted barriers underscore the complex interplay between socioeconomic factors and health outcomes in stroke recovery.

Our analysis has the following strengths: (1) large cohort of patients; (2) multicentre study; (3) data ascertainment undertaken systematically; and (4) the inclusion

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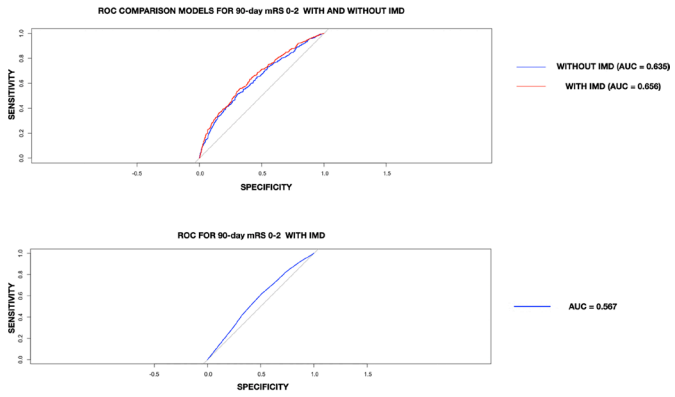


Figure 5 Receiver operating characteristic (ROC) curves for predicting 90-day modified Rankin Scale (mRS) 0–2 after mechanical thrombectomy. AUC, area under the curve; IMD, Index of Multiple Deprivation.

of patients for MT followed standardised eligibility criteria across all participating centres, ensuring consistency in clinical decision-making and minimising selection bias. Nevertheless, our study also has several limitations. First, the retrospective observational and non-randomised design inherently carries the risk of selection bias and confounding factors, despite our efforts to mitigate these through robust statistical adjustments. While we used techniques such as IPW and examined SMDs to ensure covariate balance, residual confounding from unmeasured or unrecorded variables cannot be completely excluded. For example, factors such as the quality of poststroke rehabilitation, patient adherence to follow-up care or other psychosocial determinants were not captured in our dataset and may have influenced the outcomes. It is also important to note that although our data collection was prospective—ensuring a systematic and standardised approach to capturing clinical, demographic and procedural information—retrospective analyses remain limited by the scope and granularity of the available data. Finally, while a randomised controlled trial (RCT) is the gold standard for minimising bias, conducting an RCT to investigate the impact of SES on outcomes is neither feasible nor ethical, as SES is an intrinsic patient characteristic that cannot be randomised. Thus, our study design reflects the most practical and ethical approach to exploring the role of SES in this context. Despite these limitations, our study provides valuable real-world insights into the persistent inequities in stroke outcomes associated with SES and highlights the need for targeted interventions to address these disparities. The study examines 90-day outcomes, which, while widely used in stroke research, provide limited insights into long-term recovery, recurrent events and poststroke quality of life. Finally, although the study cohort includes a balanced representation of socioeconomic groups (43.7% $IMD_{1–5}$ and 56.3% $IMD_{6–10}$), the findings are drawn from three London-based centres, which may not fully reflect populations in rural areas or regions with different healthcare systems and socioeconomic structures. As in previous studies,[19 37] we did not adjust for recurrent strokes or new comorbidities that emerged during follow-up, which may introduce some confounding in our results.

In summary, our study confirms and expands on the existing body of literature, demonstrating that SES is a critical determinant of outcomes following MT in patients who had an acute ischaemic stroke even in a universal healthcare setting in the UK. In contrast to prior studies that primarily focus on general stroke populations, our analysis of MT outcomes highlights that the influence of SES disparities on stroke outcomes remains pronounced even when access to the most effective interventions is standardised. These findings suggest that efforts to mitigate SES disparities must go beyond equalising access to advanced treatment and should address broader social determinants of health to improve poststroke recovery for more deprived SES groups of patients.

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Patient consent for publication Not applicable.

Ethics approval This study involves human participants. This study was approved by the local institutional review boards. This study has obtained approval from the UK Health Regulator Authority (Health Regulator Authority, reference number: 275260). The study has also received confirmation of capacity and capability from the Imperial College Healthcare NHS Trust. Informed consent was not a legal requirement as the research was carried out using data collected as part of routine care and any researchers outside the direct care team only had access to anonymised data. The study was conducted in accordance with the recommendations for physicians involved in research on human subjects adopted by the 18th World Medical Assembly, Helsinki 1964 and later revisions.

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