Stroke

ORIGINAL CONTRIBUTION

Socioeconomic Deprivation in Ischemic Stroke Treated With Endovascular Thrombectomy: Not All Recoveries Are Equal

Carmen Montalvo, MD*; Alvaro Garcia-Tornel, MD, PhD*; Marta Olive-Gadea, MD, PhD; Marc Rodrigo-Gisbert, MD, PhD; Manuel Requena, MD, PhD; Federica Rizzo, MD; David Rodriguez-Luna, MD, PhD; Noelia Rodriguez-Villatoro, MD, PhD; Jorge Pagola, MD, PhD; Renato Simonetti, MD; Natalia Perez de la Ossa, MD, PhD; Pol Camps-Renom, PhD; David Canovas, MD, PhD; Alan Flores, MD, PhD; Ana Rodriguez-Campello, MD, PhD; Yolanda Silva, MD, PhD; Xabier Urra, MD, PhD; Francesc Purroy, MD, PhD; Alejandro Bustamante, MD, PhD; Merce Salvat-Plana, MD, PhD; Pere Cardona, MD, PhD; Carlos Molina, MD, PhD; Marta Rubiera, MD, PhD; Marc Ribo, MD, PhD

BACKGROUND: The influence of socioeconomic deprivation on outcomes in ischemic stroke patients treated with thrombectomy remains unclear.

METHODS: We analyzed 6219 patients with ischemic stroke treated with thrombectomy between 2016 and 2023 in Catalonia, Spain. Socioeconomic deprivation was defined at the health care service area level (n=378) as the proportion of inhabitants with an annual income below $21 000. The adjusted absolute difference in the proportion of patients achieving good functional outcome (90-day modified Rankin Scale score of 0–2) between the least and most deprived areas (fifth versus 95th percentile) was estimated based on mixed effects modeling. Secondary outcomes included mortality at 90 days, 24-hour National Institutes of Health Stroke Scale score, complete reperfusion, and onset to arterial puncture time. Analyses were stratified by reference center location—Barcelona metropolitan region (fully covered by thrombectomy-capable centers) and Catalonia provincial region (dispersed population with varying center capabilities, including 3 thrombectomy-capable centers). The contribution of deprivation to between-center variance was estimated using a between-within effects model.

RESULTS: Patients from most deprived areas were less likely to achieve functional independence in metropolitan (adjusted absolute difference, 7.4% [95% CI, 2.1%–12.7%]; $P<0.01$) than provincial (adjusted absolute difference, 10% [95% CI, 2.8%–17.2%]; $P<0.01$) regions. Mortality rate, complete reperfusion, and 24-hour National Institutes of Health Stroke Scale score did not differ between areas, whereas time from onset to thrombectomy was delayed in most deprived areas of the provincial region (least deprived 226 minutes [95% CI, 196–256] versus most deprived 272 minutes [95% CI, 247–298], difference 46 minutes [95% CI, 3–90]; $P=0.02$). Average center-level socioeconomic deprivation explained a substantial proportion of between-center variability in good functional outcomes, particularly in the metropolitan region.

CONCLUSIONS: Socioeconomic deprivation is a major determinant of poor functional outcomes in patients with stroke undergoing endovascular thrombectomy in Catalonia, Spain, explaining a substantial proportion of between-center differences in outcomes. This disparity may be partially attributed to delays in acute treatment; however, postacute care factors should be evaluated as key contributors.

GRAPHIC ABSTRACT: A graphic abstract is available for this article.

Key Words: incidence ■ ischemic stroke ■ puncture ■ reperfusion ■ thrombectomy

Correspondence to: Alvaro Garcia-Tornel, MD, PhD, Stroke Unit, Department of Neurology, Hospital Universitari Vall d'Hebron, Barcelona, Spain. Email garlord900@gmail.com
*C. Montalvo and A. Garcia-Tornel contributed equally.
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Nonstandard Abbreviations and Acronyms

AAD	adjusted absolute difference
EVT	endovascular thrombectomy
LVO	large vessel occlusion
mRS	modified Rankin Scale
NIHSS	National Institutes of Health Stroke Scale
PCSA	Population and Care Service Area

Stroke is the leading cause of disability worldwide, with ischemic stroke due to large vessel occlusion (LVO) being a major contributor to long-term severe disability and death among patients with ischemic stroke.[1] In 2015, 6 randomized trials demonstrated the efficacy of endovascular thrombectomy (EVT) in patients with anterior circulation LVO.[2] These trials also highlighted the time-dependent treatment effect of EVT,[3] underscoring the urgent need to develop stroke systems of care that can provide EVT quickly, regardless of geographic or socioeconomic disparities.

Socioeconomic status is a multifaceted construct of social standing that encompasses dimensions such as income, education, employment, and social status.[4] Numerous studies have shown that stroke disproportionately affects patients experiencing socioeconomic deprivation, influencing factors such as stroke incidence,[5] severity,[6,7] time delays to hospital arrival,[8] and outcomes related to quality of life and long-term disability.[9,10] Most studies have used area-based measures of socioeconomic status across different domains to assess these relationships. Patients with stroke secondary to LVO may be particularly vulnerable to socioeconomic inequalities, as outcomes are heavily dependent on timely treatment and the availability of postacute stroke resources, which may not be equitably distributed across different levels of socioeconomic deprivation and geographic regions.[11] Moreover, most studies have included heterogeneous samples of patients with stroke with varying degrees of detail in outcome measures, limiting the generalizability and interpretability of findings to specific stroke subpopulations that may be disproportionately affected by these inequalities.

Our primary objective is to assess the association between neighborhood-level socioeconomic deprivation and outcomes in patients with acute ischemic stroke treated with EVT in Catalonia, Spain. Specifically, we aim to determine whether socioeconomic disparities in stroke outcomes vary based on the thrombectomy capabilities of the reference center and to what extent these disparities are influenced by differences in initial stroke severity, acute stroke care, or early neurological evolution.

METHODS

This article follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Ethics and Approvals

Data were collected through the Codi Ictus Catalunya registry, a government-mandated, encrypted, and anonymized registry of all patients with acute stroke attended in the stroke system of care of Catalonia. The institutional review board of Hospital Universitari Vall d'Hebron (PR(AG)334-2024) approved this retrospective study with an exemption from the requirement to obtain informed consent.

Data Availability

Deidentified aggregated data that support the findings of this study can be made available to qualified investigators on reasonable request to the corresponding author.

Study Population

The eligible population consisted of patients with acute ischemic stroke who received EVT in thrombectomy-capable centers in Catalonia, Spain, between January 2016 and December 2023. Patients were included in the study if they were independent in activities of daily living before the stroke (modified Rankin Scale [mRS] score of ≤2, with mRS scores ranging from 0 [no symptoms] to 6 [death]), were living in Catalonia at the time of stroke, had a National Institutes of Health Stroke Scale (NIHSS) score of 6 or higher (with scores ranging from 0 to 42, with higher scores indicating worse neurological deficits), and received EVT within 24 hours of stroke onset or the last known well time. The study population was stratified into 2 groups based on the thrombectomy capabilities of the patient's reference stroke center: metropolitan and provincial regions. The stratification was done because patients in the Catalonia provincial region typically experience worse outcomes and different workflow metrics compared with those in the metropolitan region, as they often require transfers to the Barcelona metropolitan region for EVT.[12] The Barcelona metropolitan region included patients whose reference stroke center maintained continuous, year-round thrombectomy capabilities throughout the study period (Figure S1). Participant data were sourced from the Codi Ictus Catalunya registry, a government-mandated database that tracks acute stroke metrics across all stroke centers in Catalonia and has published aggregated data on patients undergoing reperfusion treatments since 2016. Disability at 90 days is assessed using the mRs score based on telephone interviews conducted by certified, blinded assessors not involved in acute stroke care using structured interviews. The Codi Ictus Catalunya registry also served as the case report form repository for the RACECAT trial, a cluster-randomized trial conducted in Catalonia from March 2017 to June 2020.[13]

Socioeconomic Deprivation Measures

Individual-level socioeconomic metrics were unavailable for study participants; therefore, area-based socioeconomic metrics were used for the analysis. These metrics aggregate data from individuals residing in small geographic areas and are commonly employed in epidemiological research to examine the association between socioeconomic status and health outcomes. Some area-based socioeconomic measures focus on a single dimension of deprivation, such as income, while others integrate multiple dimensions—including income, education, employment, and social status—into a composite index that normalizes values across different domains, providing a broader assessment of socioeconomic conditions.[14,15]

Area-based socioeconomic metrics were assessed at the basic health area level (n=378), the neighborhood-level unit within the Catalonia health care system. Socioeconomic deprivation measures included an income-related measure, defined as the ratio of individuals with an annual income below \$21 000—approximately the at-risk-of-poverty threshold for a 2-adult household in Catalonia—and a composite measure, the Population and Care Service Area (PCSA) index. The PCSA index ranges from 0 to 100, with higher scores indicating greater deprivation, and was developed to address territorial inequities in Catalonia by incorporating 13 variables related to income, employment, and education.[16] Income was selected as the primary neighborhood-level exposure due to its direct association with economic status and stroke outcomes, as well as its broader generalizability, whereas the PCSA index was used for sensitivity analyses. Socioeconomic deprivation measures were standardized by subtracting the median and dividing by the interquartile range, with higher values indicating more deprived areas.

Outcome Measures

The primary outcome measure for the analysis was the degree of disability at 90 days, as assessed by the mRS. The primary outcome was the proportion of patients who were independent in activities of daily living (mRS score, 0–2). Secondary outcomes included the proportion of deceased patients (mRS score, 6) at 90 days, the early clinical course, assessed through the NIHSS score at 24 hours, time from stroke onset to first hospital arrival and thrombectomy initiation, and the degree of reperfusion at the end of the procedure, as measured by the modified Thrombolysis in Cerebral Infarction score.

Statistical Analyses

Descriptive statistics for individual-level and type of the stroke center (center-level covariate) were summarized across quartiles of the neighborhood-level income measure, treated as a continuous variable, and for each geographic region (metropolitan and provincial region). Distribution quartiles were stratified by metropolitan and provincial regions. Missing outcome data (mRS score at 90 days in 322 patients [4.8%] and in the NIHSS score at 24 hours in 951 patients [15.5%]) were handled using multiple imputation with chained equations, under the assumption that data were missing at random, with 10 imputed data sets after 5 iterations (Table S1).

To account for the study's clustered design at the neighborhood and center levels, the association between socioeconomic deprivation and outcomes was analyzed using mixed-effects binomial logistic regression for binary outcomes and negative binomial regression for continuous outcomes, with an interaction term between region and socioeconomic deprivation. These models included a nested random intercept structure for basic health areas (n=378, neighborhood-level intercepts) and their reference stroke center (n=28, center-level intercepts). The analysis employed the income-related measure (ratio of individuals with an income below \$21 000) as the primary exposure and the compound measure (PCSA index) as a sensitivity analysis and was stratified according to region (metropolitan versus provincial). Binary outcome measures are presented as the model-based average predicted probabilities for the least and most deprived areas, defined as the fifth and 95th percentiles of the distribution of the studied population.[17] Effect estimates, expressed as adjusted absolute differences (AAD), were then estimated from these predicted probabilities. We also assessed the heterogeneity in the difference of the primary outcome across prespecified covariate strata: sex (male versus female), age (≤75 versus >75 years), and stroke severity (NIHSS ≤15 [mild-to-moderate] versus NIHSS >15 [severe]). Continuous outcomes were modeled using a negative binomial distribution to account for their highly right-skewed distribution and overdispersion. Effect estimates from the negative binomial models were reported as adjusted mean differences for continuous outcomes, back-converted to the original scale, with standard errors calculated using the delta method to quantify uncertainty around point estimates. The primary and secondary outcomes analysis was adjusted for prespecified covariates known to be associated with outcomes in patients with stroke undergoing EVT or might confound or mediate the exposure-outcome relationship (Table S1).

We performed an exploratory analysis to assess the potential confounding due to the correlation of the exposure with centers, also referred to as confounding by clustering.[18] This term refers to the situation where the exposure is unevenly distributed across centers, meaning that some centers may disproportionately serve populations with higher or lower average levels of socioeconomic deprivation (Figure S2). When the exposure is correlated with the centers themselves, it creates a potential source of bias because the outcomes observed at different centers could be influenced by both the average socioeconomic deprivation and the characteristics of each center. In such cases, the apparent effect of the exposure on outcomes might be confounded by these center-level differences. To assess this potential confounding, the exposure-outcome association was decomposed into 2 components: the within-center and the between-center effect in a hybrid model.[19–22] The within-center component reflects the variability among patients within the same center, averaged over all centers. In contrast, the between-center component captures differences attributable to centers serving populations with different average levels of socioeconomic deprivation, independent of neighborhood-level measures. This model also assessed the impact of center-level average socioeconomic deprivation on between-center variability by comparing 2 nested models: 1 excluding and 1 including socioeconomic deprivation measures. By quantifying the reduction in the variance of the center-level random intercept, we estimated the extent to which center average socioeconomic deprivation explains the between-center differences in the proportion of patients with good functional outcomes. A likelihood ratio test was then used to formally assess whether including the center average exposure significantly reduced between-center variability.[23,24]

All effect size estimates were provided with their 95% CIs, without adjustment for multiple comparisons. All analyses were performed using R version 4.1.1 (R Development Core Team) with the glmmTMB, mice, and marginal effects packages.

RESULTS

Of 7903 patients treated with EVT between January 2016 and December 2023 in Catalonia, a sample of 6219 patients was included in the analysis (Figure S3). Mean age was 72±14 years, 3207 (52%) patients were male, and the median NIHSS score before EVT was 17 (interquartile range, 11–21). Intravenous thrombolysis was administered in 2514 patients (41%). Baseline characteristics, including prespecified covariates for the analysis, are presented for each quartile of the distribution in each region in Table 1. The distribution of socioeconomic deprivation measures by region is presented in Figure 1; Figure S4.

Primary Outcome

The distribution of the mRS score by quartiles of the distribution for each socioeconomic measure (income and compound) is presented in Figure 2; Figure S5A. Among the patients living in the metropolitan region, the average probability of good functional outcome was 44.2% (95% CI, 41.1%–47.1%) in the least deprived areas, as compared with 36.8% (95% CI, 33.7%–39.8%) in the most deprived areas (AAD, 7.4% [95% CI, 2.1%–12.7%]; $P<0.01$). Among patients in the provincial region, the average probability was 39% (95% CI, 34%–44.1%) in the least deprived areas and 29% (95% CI, 26%–32%) in the most deprived areas (AAD, 10% [95% CI, 2.8%–17.2%]; $P<0.01$; Figure 3). Result based on the PSCA index as the exposure showed similar results (Figure S5B), with an AAD of 6.3% (95% CI, 0.9%–9.2%; $P=0.02$) in the metropolitan region and an AAD of 10.5% (95% CI, 2.48%–18.6%; $P<0.01$) in the provincial region. No significant heterogeneity was observed in the analysis of the primary outcome across strata of sex, age, or stroke severity (Table 2). The exploratory hybrid model showed that the observed differences were within-center in the provincial region (within-center AAD; metropolitan region 3.6% [95% CI, −10.6% to 8.4%]; $P=0.12$ versus provincial region 9.5% [95% CI, 2.3%–16.8%]; $P=0.01$) and between-center in the metropolitan region (between-center AAD; metropolitan region, 7.9% [95% CI, 3.7%–12.2%]; $P<0.01$ versus provincial region, 3.1% [95% CI, −2.3% to 8.5%]; $P=0.21$; Figure S6). Inclusion of the center-level average exposure substantially reduced between-center variability estimates in both metropolitan and provincial regions, indicating that average socioeconomic deprivation at the center level accounted for much of the previously unexplained variability—particularly in metropolitan areas (Table S2; Figure S7).

Secondary Outcomes

Secondary outcomes are summarized in Table 3. Mortality rate, NIHSS scores at 24 hours, and the proportion of patients achieving complete reperfusion did not differ significantly between the least deprived or most deprived areas in the metropolitan or provincial regions. Nonetheless, workflow times were prolonged for patients in the most deprived areas of the provincial region. In the provincial region, the mean time from symptom onset to first hospital admission was 226 minutes (95% CI, 196–256) in the least deprived areas and 272 minutes (95% CI, 247–298) in the most deprived areas (mean difference, 46 minutes [95% CI, 3–90]). Similarly, the mean time from symptom onset to arterial puncture was 348 minutes (95% CI, 320–376) in the least deprived areas and 394 minutes (95% CI, 372–417) in the most deprived areas (mean difference, 46 minutes [95% CI, 7–85]). Figure 4 depicts the change in NIHSS score from baseline to 24 hours and the time from symptom onset to arterial puncture, stratified by quartiles of the income distribution.

DISCUSSION

Socioeconomic deprivation has increasingly been recognized as a significant determinant of stroke outcomes across diverse geographic regions and study designs. Our study, conducted within a public stroke system with universal access to stroke care, demonstrated that patients with LVO undergoing EVT who resided in more socioeconomically deprived areas had significantly lower odds of achieving independence in activities of daily living at 90 days. This disparity was even more pronounced among patients in the catchment areas of centers that did not provide around-the-clock thrombectomy services during the study period. In these settings—serving more dispersed populations across rural, small urban, and suburban areas—the absolute difference in 90-day functional independence was 10% in the broader Catalonia provincial region, and 7% in the more homogeneous Barcelona metropolitan region.

Early clinical course—as reflected by the NIHSS score at 24 hours, an established surrogate marker of disability at 90 days[25]—did not differ across socioeconomic deprivation levels in either region, suggesting that postacute stroke care may play a critical role. A key limitation of the registry used in this study is its focus on the acute stroke phase, without detailed data on subacute or long-term care, including rehabilitation resources, lifestyle factors (such as physical activity and cardiovascular risk management), medication adherence, or regional infrastructure for patients with disabilities. Given its more dispersed population and higher proportion of rural areas, the Catalonia provincial region may have reduced access to these critical poststroke resources, as in-home support services, housing, and rehabilitation facilities.

An important consideration in interpreting our findings is the differential impact of Catalonia's centralized stroke care model across geographic regions. The provincial region's care structure, where only 45% of patients arrive directly at thrombectomy-capable centers compared

Table 1. Baseline Characteristics for Each Quartile Distribution of Each Region

	Barcelona metropolitan region				Catalonia provincial region			
	Quartile 1, n=892	Quartile 2, n=888	Quartile 3, n=900	Quartile 4, n=864	Quartile 1, n=670	Quartile 2, n=674	Quartile 3, n=665	Quartile 4, n=666
Age, y, median (IQR)	77 (67–84)	75 (66–81)	75 (64–82)	73 (62–81)	75 (63–82)	74 (63–81)	73 (62–82)	73 (63–81)
Sex (male), n (%)	433 (48%)	435 (49%)	460 (51%)	447 (52%)	346 (52%)	400 (59%)	376 (56%)	370 (55%)
Prestroke mRS								
mRS score 0, n (%)	556 (62%)	524 (59%)	576 (64%)	565 (65%)	458 (68%)	454 (67%)	461 (69%)	443 (67%)
mRS score 1, n (%)	174 (20%)	196 (22%)	181 (20%)	153 (18%)	119 (18%)	119 (18%)	124 (19%)	122 (18%)
mRS score 2, n (%)	162 (18%)	168 (19%)	143 (16%)	146 (17%)	93 (14%)	93 (14%)	80 (12%)	101 (15%)
Hypertension, n (%)	533 (60%)	506 (57%)	470 (52%)	453 (52%)	354 (53%)	357 (53%)	394 (59%)	378 (57%)
Dyslipidemia, n (%)	383 (43%)	354 (40%)	340 (38%)	313 (36%)	241 (36%)	245 (36%)	265 (39%)	247 (37%)
Diabetes, n (%)	149 (17%)	147 (17%)	163 (18%)	175 (20%)	102 (15%)	120 (18%)	133 (20%)	118 (18%)
Smoking, n (%)	111 (12%)	113 (13%)	121/13%)	138 (16%)	93 (14%)	88 (13%)	95 (14%)	105 (16%)
Congestive heart failure, n (%)	49 (5%)	56 (6%)	68 (7%)	56 (6%)	43 (6%)	65 (9%)	52 (7%)	48 (7%)
Peripheral vascular disease, n (%)	26 (3%)	31 (4%)	32 (4%)	30 (4%)	18 (3%)	23 (4%)	16 (3%)	9 (2%)
Atrial fibrillation, n (%)	222 (25%)	218 (25%)	187 (21%)	187 (22%)	125 (19%)	145 (21%)	135 (20%)	146 (22%)
Coronary artery disease, n (%)	102 (11%)	88 (10%)	83 (9%)	110 (13%)	79 (12%)	54 (8%)	71 (11%)	59 (9%)
Anticoagulation therapy, n (%)	127 (14%)	155 (17%)	133 (15%)	126 (15%)	87 (13%)	87 (13%)	67 (10%)	85 (13%)
NIHSS score, median (IQR)	17 (11–21)	16 (11–21)	17 (11–20)	17 (12–21)	18 (12–21)	17 (12–21)	18 (12–21)	17 (12–20)
Unknown stroke onset, n (%)	226 (25%)	261 (29%)	269 (30%)	275 (32%)	207 (31%)	223 (33%)	215 (32%)	236 (35%)
Thrombolytic treatment, n (%)	405 (45%)	343 (39%)	345 (39%)	334 (39%)	292 (44%)	266 (40%)	303 (46%)	283 (42%)
Nighttime arrival, n (%)	213 (24%)	208 (24%)	240 (27%)	240 (28%)	180 (27%)	161 (24%)	180 (27%)	171 (26%)
Nonholiday weekdays, n (%)	624 (70%)	629 (71%)	641 (71%)	586 (68%)	456 (68%)	459 (68%)	457 (69%)	461 (69%)
Arrival mode, n (%)								
Stroke code	652 (73%)	654 (74%)	676 (75%)	657 (76%)	501 (75%)	542 (80%)	555 (84%)	534 (80%)
Intrahospital stroke	94 (11%)	89 (10%)	122 (14%)	106 (12%)	80 (12%)	61 (9%)	44 (6%)	43 (6%)
No stroke code	146 (16%)	145 (16%)	102 (11%)	101 (12%)	89 (13%)	71 (11%)	66 (10%)	89 (14%)
Reference hospital type, n (%)								
TCC (metropolitan)	892(100%)	888 (100%)	900 (100%)	864 (100%)				
TCC (provincial)					135 (20%)	185 (27%)	296 (44%)	261 (39%)
Primary stroke center					289 (43%)	130 (19%)	159 (24%)	135 (20%)
Telestroke center					246 (37%)	359 (53%)	210 (32%)	270 (41%)
Thrombectomy at first center, n (%)	832 (93%)	799 (90%)	836 (93%)	797 (92%)	302 (45%)	333 (49%)	280 (42%)	295 (44%)
ASPECTS score, median (IQR)	9 (8–10)	9 (8–10)	9 (8–10)	10 (8–10)	9 (8–10)	9 (8–10)	10 (8–10)	9 (8–10)
Occlusion location, n (%)								
Intracranial ICA	131 (15%)	122 (14%)	122 (14%)	129 (15%)	81 (12%)	96 (14%)	95 (14%)	95 (14%)
M1 MCA	474 (53%)	465 (52%)	445 (49%)	441 (51%)	363 (54%)	356 (53%)	381 (57%)	371 (56%)
M2 MCA	160 (18%)	169 (19%)	178 (20%)	164 (19%)	131 (20%)	123 (18%)	108 (16%)	113 (17%)
Basilar artery	35 (4%)	56 (6%)	72 (8%)	58 (7%)	36 (5%)	49 (7%)	32 (5%)	33 (5%)
Others	92 (10%)	76 (8%)	83 (9%)	72 (8%)	59 (9%)	50 (7%)	49 (7%)	54 (8%)
Tandem occlusion, n (%)	111 (12%)	121 (14%)	146 (16%)	165 (19%)	131 (19%)	118 (17%)	106 (16%)	114 (17%)

ASPECTS indicates Alberta Stroke Program Early CT Scale; ICA, internal carotid artery; IQR, interquartile range; MCA, middle cerebral artery; mRs, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; and TCC, thrombectomy-capable center.

with 90% to 93% in the metropolitan area, creates additional barriers that compound socioeconomic disparities. The centralized care model appears to provide more homogeneous outcomes in the metropolitan area, thereby attenuating—though not eliminating—the impact of socioeconomic deprivation on functional outcomes. Conversely, in the provincial region, the combination of longer distances to specialized centers and reduced direct access to thrombectomy facilities creates a double burden that disproportionately affects patients from deprived areas, who may have fewer resources to overcome these geographic and logistical challenges.

In the literature, poor neurological outcomes in socioeconomically deprived areas are often attributed

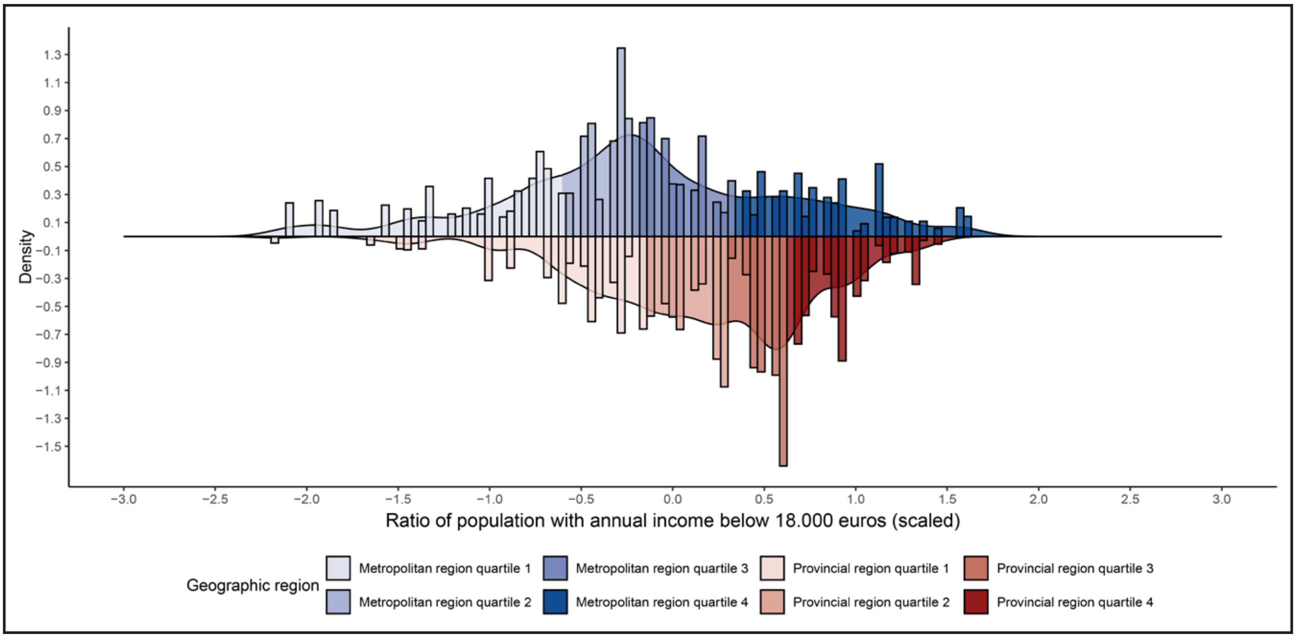

Figure 1. Distribution of the ratio of individuals with an annual income below $21 000 per region and quartiles.
Density plot and histogram representing the distribution of the socioeconomic deprivation measure (ratio of individuals with an annual income below $21 000) after robust scaling, stratified by region (provincial vs metropolitan). Representations are colored by quartiles of the distribution within each region.

to multiple factors, including a higher incidence of ischemic stroke and cardiovascular risk factors, lower-quality medical care, reduced access to reperfusion therapies, and delayed treatment initiation.[17] Additionally, patients in these areas tend to present with greater stroke severity, as measured by the NIHSS scale.[9] A recent study from Canada examined the odds of receiving reperfusion treatment while accounting for hospital and neighborhood clustering. The study found that patients in deprived areas had lower odds of receiving reperfusion therapy; however, functional outcomes were not assessed.[26]

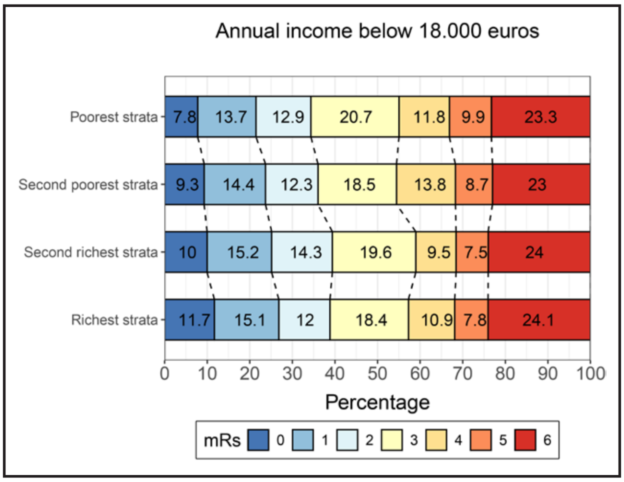

Figure 2. Distribution of the modified Rankin Scale at 90 days by quartiles of the distribution of socioeconomic deprivation.
Stacked barplot representing the distribution of the modified Rankin Scale at 90 days based on quartiles of the distribution of the area-based ratio of individuals with annual income below $21 000.

Different studies have suggested that long distances to thrombectomy-capable centers in deprived areas may contribute to worse outcomes.[8] Patients in deprived areas of the provincial region experienced a mean delay of 46 minutes from symptom onset to hospital admission and thrombectomy initiation, which could account for the larger absolute difference observed in this region. The underlying causes of these workflow delays likely involve multiple factors, including greater geographic distances to thrombectomy centers, potentially longer EMS response times, and possible delays in symptom recognition or health care-seeking behavior among patients in deprived areas. Without granular data on individual workflow components, we cannot definitively determine which factors primarily drive these observed delays. Nonetheless, in our cohort, differences in functional outcome could not be explained solely by delays in workflow times, at least in the metropolitan region where workflow times were comparable, and the quality of reperfusion and early clinical course were comparable across socioeconomic strata.

Decomposition into within-center and between-center effects revealed distinct patterns of socioeconomic disparities. In the Barcelona metropolitan region, outcome differences were primarily driven by variations between centers with differing average levels of socioeconomic deprivation. In contrast, in the more geographically dispersed provincial region, disparities were largely attributable to variations among basic health areas within the

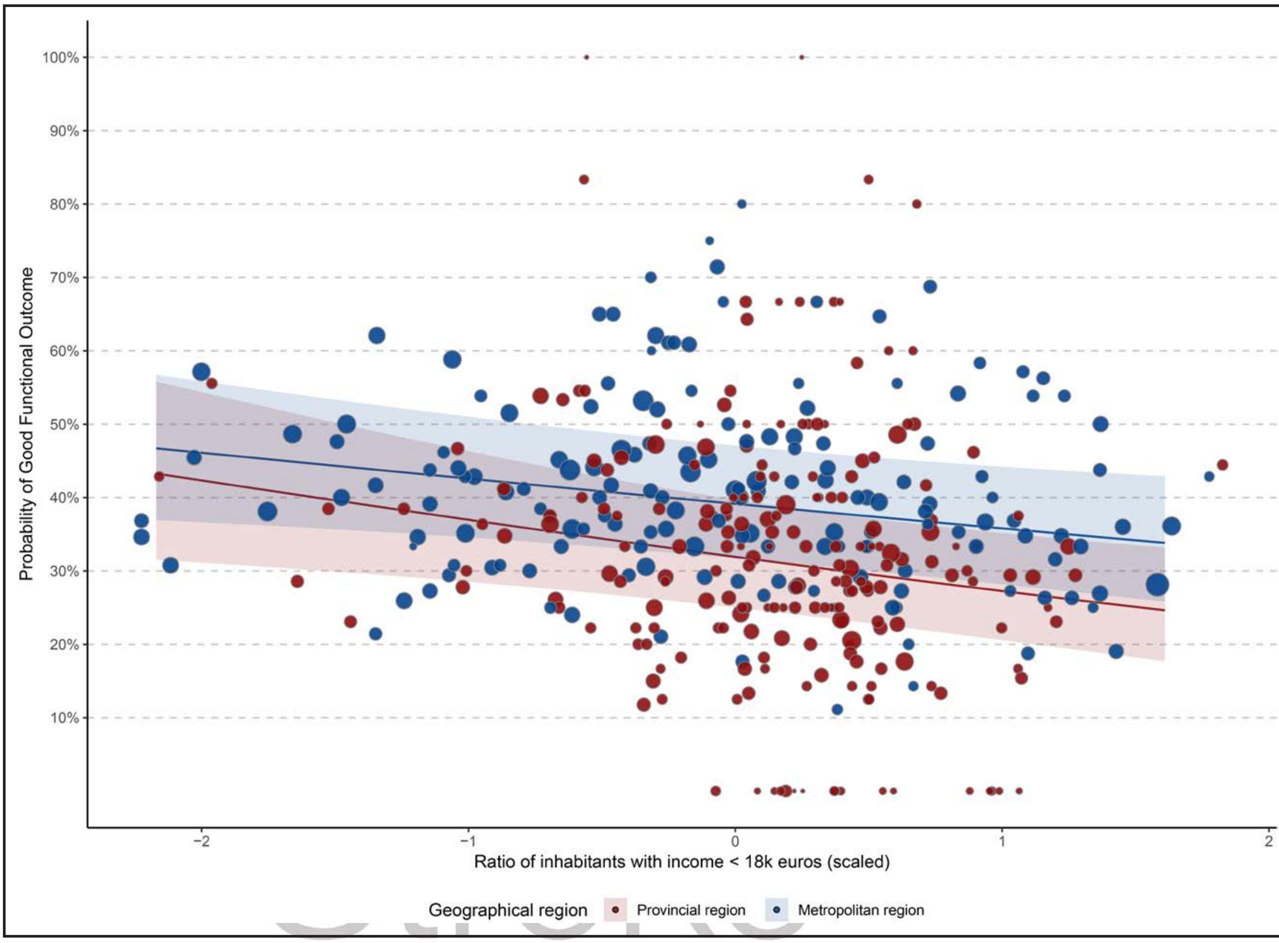

Figure 3. Probability of good functional outcome according to socioeconomic deprivation.
Graphical representation of the marginal effects of socioeconomic deprivation on the probability of good functional outcome (mRS score at 90 days of 0–2). Marginal effects (lines and 95% CIs) as a function of the socioeconomic deprivation measure are stratified by region. Dots represent the crude proportion of good functional outcome for each basic health area (n=378) included in the population. Dots are sized according to cluster size.

same center. Between-center differences in functional outcomes after stroke have traditionally been analyzed in relation to hospital capabilities, stroke care infrastructure, and workflow efficiency metrics.[23,27] Although these factors undoubtedly might contribute to outcome disparities, our findings highlight the pivotal role of socioeconomic deprivation at the center level. In our study, the center average socioeconomic deprivation accounted for 94% of the between-center variability in the proportion of patients with good functional outcome, after accounting for individual-level variables and type of stroke center. This suggests that, beyond differences in hospital resources and clinical workflows, poverty is a major determinant of disparities in functional recovery among patients with LVO stroke treated with EVT.

The regional pattern of these disparities differed. In the metropolitan region, where centers are more homogenous and serve more densely populated areas with shorter distances to hospital acute care, between-center differences in socioeconomic status were the dominant driver of outcome variation. This aligns with prior research indicating that hospitals in wealthier areas often benefit from better infrastructure, additional specialized services, and potentially greater access to postacute rehabilitation.[28,29] In contrast, in the more geographically dispersed provincial region, outcome disparities were primarily driven by within-center differences, meaning that socioeconomic inequalities influenced the outcome more significantly within individual hospital catchment areas rather than across different centers. While access to acute stroke care is likely still equally guaranteed regardless of socioeconomic status, poststroke subacute care may still depend on socioeconomic factors. Ensuring equitable outcomes also depends on strengthening the continuum of care—from prehospital systems and acute treatment to rehabilitation and long-term support—so that the benefits of advanced stroke therapies, such as EVT, translate into meaningful functional recovery across all socioeconomic groups.

In our cohort, no significant differences were observed in mortality rates at 90 days, although differences were found in good functional outcomes. This contrasts with

Table 2. Subgroup Analysis According to Age, Sex, and Stroke Severity for the Primary Outcome (Proportion of Patients With Good Functional Outcome at 90 Days)

		Least deprived areas (fifth percentile)*	Most deprived areas (95th percentile)	Adjusted difference	*P* interaction
Sex	Male	44.2% (41.1%–47.4%)	35.9% (33.4%–38.3%)	8.4% (3.9%–12.9%)	0.56
	Female	38.9% (35.9%–41.9%)	31.1% (28.6%–33.6%)	7.8% (3.5%–12%)	
Age	Young (≤75 y)	50.3% (47.1%–53.5%)	42.5% (39.9%–45.1%)	7.7% (3.1%–12.5%)	0.67
	Old (>75 y)	30.7% (27.9%–33.6%)	24.3% (22%–26.7%)	6.4% (2.4%–10.4%)	
Stroke severity	Mild (NIHSS ≤15)	55.3% (52.2%–58.5%)	46.5% (43.7%–49.3%)	8.8% (4.1%–13.5%)	0.24
	Severe (NIHSS >15)	32.2% (29.3%–35.1%)	24.6% (22.5%–26.7%)	7.6% (3.5%–11.7%)	

NIHSS indicates the National Institutes of Health Stroke Scale.

*Model-based estimates with 95% CI for the fifth and 95th percentile of the distribution of the exposure (ratio of inhabitants with an income below $21 000).

a previous report from our region,[30] which found differences in short- and long-term mortality (30 days and 1 year, respectively) using individual-level income as the exposure, while the PCSA index was only associated with short-term mortality. Several factors could explain these discrepancies. First, the cohort composition differs: our study focused on patients with LVO treated with EVT to allow comparison within a more homogeneous population with higher baseline stroke severity, while the previous study included an unselected stroke population. Second, the timing of assessments varies, with different end points potentially influencing observed trends. Third, differences in exposure measures and their sensitivity to capturing socioeconomic disparities could contribute to the variation in findings. Lastly, advances in stroke treatments such as widespread access to reperfusion therapies like mechanical thrombectomy, improvements in postacute care, and the extension of the therapeutic window for reperfusion therapies may have contributed to reducing differences between socioeconomic strata.

Our study offers a novel perspective on the relationship between socioeconomic deprivation, regional resources, and stroke outcomes, particularly functional recovery, among patients with LVO stroke undergoing EVT. Nonetheless, several limitations should be acknowledged. First, despite the prospective nature of the Codi Ictus Catalunya registry, our analysis is retrospective, which inherently carries methodological limitations, such as potential biases in data collection and analysis. Additionally, our findings are situated within the context of the Catalonian health care system, which is a publicly funded model offering universal health care. Specifically, in Catalonia, a high-quality and efficient stroke care network has been established, partly due to prior interventions to reduce inequalities in access to reperfusion treatments, like the RACECAT trial.[15] This system ensures timely reperfusion treatment for all

Table 3. Primary and Secondary Outcomes

		Least deprived areas (fifth percentile)*	Most deprived areas (95th percentile)*	Adjusted difference†	*P* value
Primary outcome					
Good functional outcome (mRs score, 0–2 at 90 d)	Metropolitan region	44.2% (41.1%–47.1%)	36.8% (33.7%–39.8%)	7.4% (2.1%–12.7%)	<0.01
	Provincial region	39.2% (34.2%–44.1%)	29.2% (26.1–32.2%)	10% (2.8%–17.2%)	<0.01
Secondary outcomes					
Mortality rate (mRs 6 at 90 d)	Metropolitan region	21.7% (18.8%–24.6%)	21.5% (18.4–24.6%)	0.2% (−4.2% to 4.6%)	0.92
	Provincial region	27.7% (22.5%–32.9%)	25.3% (22–28.6%)	2.4% (−5.1% to 9.8%)	0.53
NIHSS score at 24 h	Metropolitan region	10.9 (10.1–11.7)	10.9 (10.1–11.8)	0 (−1.1 to 1.2)	0.98
	Provincial region	12.4 (11–13.8)	13.3 (12.3–14.3)	0.9 (−2.9 to 1.2)	0.41
Time from onset to first hospital arrival, min	Metropolitan region	253 (229–278)	243 (218–267)	−10 (−40 to 19)	0.47
	Provincial region	226 (196–256)	272 (247–298)	46 (3–90)	0.04
Time from onset to arterial puncture, min	Metropolitan region	314 (295–333)	295 (277–314)	−19 (−40 to 3)	0.09
	Provincial region	348 (320–376)	394 (372–417)	46 (7–85)	0.02
Complete reperfusion (mTICI score, 2C–3)	Metropolitan region	64% (61%–68%)	62% (58%–67%)	−2% (−7% to 4%)	0.49
	Provincial region	58% (52%–64%)	60% (56%–64%)	2% (−6% to 10%)	0.61

mTICI indicates modified thrombolysis in cerebral infarction; mRs, modified Rankin Scale; and NIHSS, National Institutes of Health Stroke Scale.

*Proportions and continuous measures are presented as model-based estimates with 95% CI for the fifth and 95th percentile of the distribution of the exposure (ratio of inhabitants with an income below $21 000).

†Effect measures represent the absolute difference for binary outcomes and mean difference for continuous outcomes, along with 95% CIs derived from mixed-effect models. For continuous outcomes, effect measures are back-transformed based on the delta method.

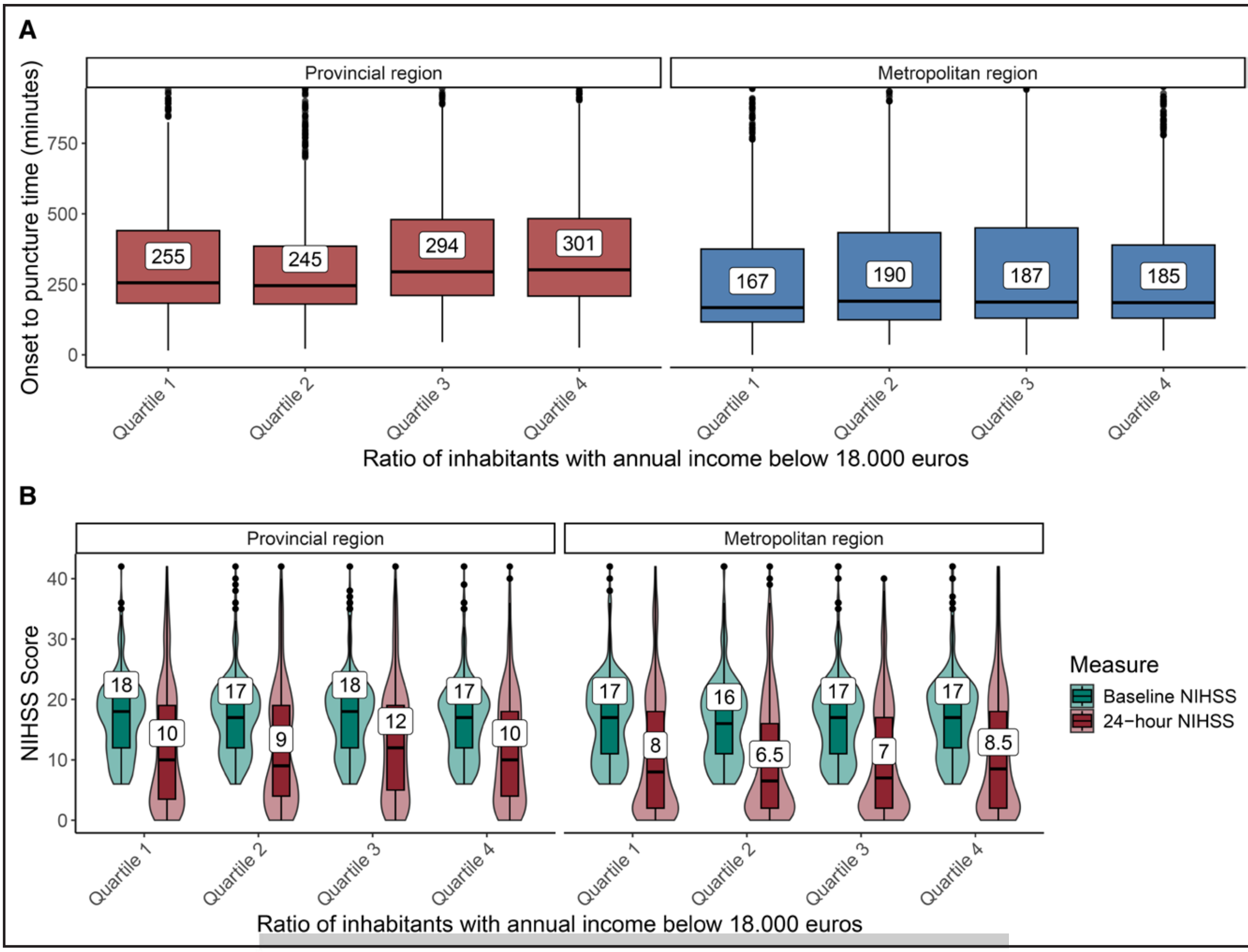

Figure 4. Time from onset to arterial puncture and early clinical course among included patients.
Descriptive statistics represented as bar plots comparing (**A**) time from symptom onset to arterial puncture and (**B**) early neurological evolution, based on baseline National Institutes of Health Stroke Scale (NIHSS) and 24-hour NIHSS scores. Descriptives are stratified according to quartile of the distribution of the socioeconomic deprivation measure and region.

residents with minimal waiting times, at no cost. Given this well-developed infrastructure, the applicability of our results may be limited to countries with similar health care settings. In regions with less access to comprehensive stroke care, the observed relationships between socioeconomic deprivation and stroke outcomes could differ significantly. Another key limitation is the use of area-based socioeconomic measures, rather than individual-level data. This approach, while practical, introduces the risk of ecological fallacy, where group-level associations may not accurately reflect individual-level outcomes. Consequently, caution should be exercised when attributing the observed associations to individuals. Moreover, socioeconomic status is a multifaceted construct, and there is no universally accepted classification system. In our study, we utilized an income-based metric as the primary exposure, but other studies may employ different indicators, such as educational attainment, employment status, or family-based measures. These various metrics, while correlated, are not interchangeable, and each provides a distinct perspective on socioeconomic status. Furthermore, our study was limited by the lack of data on other important factors, such as postacute care interventions, rehabilitation services, lifestyle behaviors, and medication adherence, all of which could impact long-term recovery. Finally, our analysis focused on patients with good prestroke functional status (mRS score, 0–2) with a moderate-severe clinical severity and LVO strokes who underwent EVT. This selection could introduce bias, as these stroke subtypes are generally associated with worse neurological outcomes and greater disability. Socioeconomic disparities may exert a differing effect in this particular subtype of ischemic stroke. Future research should aim to address these gaps by integrating both individual-level data and postacute care information to gain a more comprehensive understanding of the factors influencing stroke recovery.

CONCLUSIONS

Our study highlights the influence of socioeconomic inequalities on poststroke functional outcomes, despite universal access to acute stroke care, and its influence on outcomes at the center-level. Patients in more deprived areas had worse functional recovery, particularly in centers without around-the-clock thrombectomy services. Our results suggest that this difference might partially arise from differences in postacute care and rehabilitation access, rather than acute treatment quality. Future research should incorporate individual-level data and long-term care factors to better understand and mitigate these inequalities.

ARTICLE INFORMATION

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Affiliations

Stroke Unit, Department of Neurology, Hospital Universitari Vall d'Hebron, Barcelona, Spain (C. Montalvo, A.G.-T., M.O.-G., M.R.-G., M. Requena, F.R., D.R.-L., N.R.-V., J.P., R.S., C. Molina, M. Rubiera, M. Ribo). Stroke Unit, Department of Neurology, Hospital de la Santa Creu i Sant Pau, Barcelona, Spain (N.P.d.l.O., P.C.-R.). Stroke Unit, Department of Neurology Consorci Corporació Sanitària Parc Taulí de Sabadell, Spain (D.C.). Stroke Unit, Department of Neurology, Hospital Universitari Joan XXIII, Tarragona, Spain (A.F.). Stroke Unit, Department of Neurology, Hospital del Mar, Barcelona, Spain (A.R.-C.). Stroke Unit, Hospital Universitari Josep Trueta, Girona, Spain (Y.S.). Stroke Unit, Hospital Clínic, Barcelona, Spain (X.U.). Stroke Unit, Department of Neurology, Hospital Universitari Arnau de Vilanova de Lleida, Spain (F.P.). Stroke Unit, Hospital Universitari Germans Trias i Pujol, Badalona, Spain (A.B.). Stroke Program, Catalan Health Department, Agency for Health Quality and Assessment of Catalonia (AQuAS) (M.S.-P.). CIBER Epidemiología y Salud Pública (CIBERESP), Barcelona, Spain (M.S.-P.). Stroke Unit, Hospital Universitari Bellvitge, L'Hospitalet de Llobregat, Spain (P.C.).

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Supplemental Material

Tables S1 and S2
Figures S1–S6
STROBE Checklist

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