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HIV and Acute Stroke Hospitalizations in the United States, 2016–2023: A National Inpatient Sample Analysis

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Abstract

Background/Objective

Stroke is an important complication among people living with human immunodeficiency virus (HIV) (PLWH), but contemporary national data on in-hospital outcomes are limited. We examined trends and in-hospital outcomes of acute stroke hospitalizations with HIV in the United States.

Methods

We performed a retrospective, cross-sectional, survey-weighted analysis of the 2016–2023 National Inpatient Sample. Adult non-elective acute stroke hospitalizations were grouped by HIV status. The primary outcome was in-hospital mortality; secondary outcomes were length of stay (LOS), hospitalization cost and discharge disposition. Multivariable survey-weighted regression, propensity-score matching and a principal-diagnosis sensitivity analysis were used.

Results

Of an estimated 3,534,119 stroke hospitalizations, 19,530 (0.6%) involved PLWH, with no significant temporal trend (odds ratio [OR] per year 1.011; 95% confidence interval [CI] 0.995–1.023). PLWH were younger (mean age 55.7 vs 68.4 years) and more often male (70% vs 51%), Black (57% vs 18%) and Medicaid-insured (32% vs 11%). HIV was not independently associated with in-hospital mortality (adjusted OR 0.94; 95% CI 0.84–1.06) or LOS (− 0.32 days; 95% CI − 0.83 to 0.19) and was associated with lower cost (− US$2,904; 95% CI − 4,851 to − 958). Among principal-diagnosis strokes, HIV was associated with lower mortality (adjusted OR 0.74; 95% CI 0.61–0.90). The HIV–mortality association weakened with age (interaction OR 0.983 per year; P = .001).

Conclusions

In the antiretroviral therapy era, HIV was not independently associated with higher in-hospital stroke mortality, LOS or cost. PLWH with stroke are younger and socially disadvantaged, supporting earlier, targeted prevention and equitable access to acute stroke care.

Introduction

The fact that effective antiretroviral therapy (ART) is now widely available has greatly altered the natural course of human immunodeficiency virus (HIV) infection. What was previously mainly a quickly progressing and frequently fatal illness is now a chronic condition for a growing number of people living with HIV (PLWH), with survival extending into older ages and an increasing number of non-AIDS-related comorbidities emerging. As a result, cardiovascular and cerebrovascular diseases have become more

important clinically among this group [1, 2]. Stroke, in particular, has become an increasingly significant complication since it not only shows the buildup of the usual vascular risk factors associated with aging but also indicates biological processes that may be directly linked to HIV infection and its treatment [3, 4].

Observational studies and meta-analyses consistently show that people living with HIV have a greater risk of having a stroke than do those without HIV. A systematic review and meta-analysis of longitudinal studies found that HIV infection was linked to an increased risk of any type of stroke, of ischemic stroke, and of intracranial hemorrhage when compared with people who do not have HIV [5]. More recent evidence has also shown that people living with HIV have an excess risk of both ischemic and hemorrhagic stroke [6]. The estimates of the stroke burden also indicate that cerebrovascular disease remains a clinically significant problem in the current HIV population, especially since the number of older adults living with HIV is still increasing [7]. Even though the amount of risk differs from one setting and study population to another, the evidence available shows that HIV infection is an important factor in the development of cerebrovascular disease and not simply a coincidental comorbidity.

The reasons why HIV leads to stroke are multiple. While traditional vascular risk factors such as hypertension, diabetes, dyslipidemia, and smoking are still important, they do not entirely account for the higher cerebrovascular risk found among people living with HIV [3, 4]. Even when effective antiretroviral therapy is being used, persistent immune activation and inflammation, endothelial dysfunction, accelerated atherosclerosis, and vascular injury associated with HIV may all play a part in the development of cerebrovascular disease [1–3]. Moreover, lower CD4 cell counts and uncontrolled HIV viremia have been linked to an increased risk of stroke, which indicates that immunosuppression and continuous viral activity are involved in the disease's development [3, 8]. In different clinical situations, opportunistic infections, coagulopathy, HIV-associated vasculopathy, and immune reconstitution phenomena may also contribute to strokes and may affect the types of stroke that occur [9, 10].

The connection between ART and cerebrovascular disease is also complicated. It is essential to achieve early and continued viral suppression if HIV-related morbidity is to be reduced, since this may help to lessen some of the inflammatory and immunological mechanisms linked to vascular injury. On the other hand, the long-term metabolic effects of some antiretroviral therapies and the greater life expectancy obtained as a result of effective treatment may change an individual's overall cardiovascular risk [3, 11]. Consequently, stroke in people living with HIV cannot be explained merely by conventional risk factors or by HIV-related mechanisms on their own; it occurs in the context of a changing clinical situation influenced by ageing, comorbidities, immune status, viral control, and exposure to treatment.

Even though there has been considerable advance in our understanding of the epidemiology and mechanisms of HIV-associated stroke, there are still some unanswered questions concerning the current level of inpatient care and clinical outcomes for people with HIV in the United States. Most of the research that already exists has been concerned with stroke incidence, risk factors, or specific clinical groups rather than with comparable studies of hospitalized patients with and without HIV [3–7]. As a

result, current estimates of the fraction and total number of acute stroke hospitalizations among people with HIV during the ICD-10-CM period are still very limited. It is also not clear whether HIV status is independently linked to differences in in-hospital mortality, length of stay, hospitalization cost, or discharge disposition when demographic characteristics, socioeconomic factors, comorbidity burden, clinical severity, and hospital characteristics are taken into account.

Another area that needs to be studied is the treatment of acute stroke in people living with HIV. Although intravenous thrombolysis and mechanical thrombectomy are established parts of care for acute ischemic stroke, nationally representative evidence looking at their use and their link with in-hospital outcomes among patients who are HIV-positive is still scarce. It might therefore be useful to understand the factors that predict adverse outcomes in this group, since such information cannot be obtained simply by comparing HIV-positive and HIV-negative patients. These types of analyses could also help to clarify whether demographic, socioeconomic, clinical, or hospital-level characteristics lead to differences in outcomes.

The COVID-19 pandemic has introduced another aspect to this issue. It greatly disturbed the delivery of healthcare and was linked to changes in the way strokes were presented, in the pattern of hospitalizations, and in the provision of acute stroke care [12–14]. People living with HIV might have suffered extra vulnerabilities because of the disruption of regular care, differences in access to healthcare, and the effects of having a concurrent infection with SARS-CoV-2. Yet it has not been properly established in nationally representative data whether the pandemic period altered the relationship between HIV status and in-hospital stroke outcomes.

The National Inpatient Sample (NIS) offers a means of dealing with these gaps by looking at cases of acute stroke in a wide variety of hospitals and among different patient groups in the United States. The current study, which makes use of survey-weighted NIS data from 2016 to 2023, seeks to describe the temporal trends in acute stroke hospitalizations associated with HIV, compare the in-hospital outcomes for patients with and without HIV, and determine the factors that predict adverse outcomes among those with HIV who have had a stroke. The study will also investigate whether the link between HIV and in-hospital mortality varies according to demographic characteristics, stroke subtype, geographic region, or the period during which the COVID-19 pandemic was occurring. By giving up-to-date national estimates covering the entire ICD-10-CM period, this analysis hopes to make clear how the inpatient burden of stroke among people living with HIV has changed over time and to highlight the areas where outcome disparities may still exist.

Methods

Study design and data source

The National Inpatient Sample (NIS) is a comprehensive dataset of the United States (US) that is part of the Healthcare Cost and Utilization Project (HCUP) [15]. It is the largest publicly available all-payer

inpatient health care database in the US, sponsored by the Agency for Healthcare Research and Quality (AHRQ). It comprises discharge data obtained from a 20% stratified sample of discharges across US community hospitals, approximating a nationally representative sample when discharge weights are applied. The dataset includes information on hospital stays, specifically patient demographics, hospital characteristics, insurance, and primary and secondary diagnoses.

We used the NIS to perform a retrospective, cross-sectional, survey-weighted analysis of the 2016–2023 NIS data to characterize national temporal trends in the burden of HIV infection among acute stroke hospitalizations, to compare in-hospital outcomes between stroke hospitalizations with and without HIV, and to identify predictors of adverse outcomes within the HIV-positive stroke population. International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes were used to identify primary and secondary diagnoses, and International Classification of Diseases, Tenth Revision, Procedure Coding System (ICD-10-PCS) codes were used to identify procedures [16]. We selected the years 2016–2023 as they span the full ICD-10-CM coding era, capture both the pre-pandemic and pandemic periods, and represent the most recent data available at the time of analysis.

Because NIS_STRATUM and HOSP_NIS values are reassigned independently each data year and are not unique across years, a year-specific stratum identifier (admission year combined with NIS_STRATUM) and a year-specific hospital cluster identifier (admission year combined with HOSP_NIS) were constructed before pooling the 2016–2023 files, so that hospitals and strata from different years were not erroneously treated as identical sampling units. All analyses then accounted for the complex survey design of the NIS using the discharge weight (DISCWT) together with these year-specific stratum and hospital cluster identifiers, with single-unit strata centered at the overall mean. Because analyses were restricted to a stroke subpopulation, all estimates were generated using subpopulation commands so that variance was estimated correctly across the full design.

Study population

The study population included adult discharges aged 18 years or older with a diagnosis of acute stroke identified using ICD-10-CM codes I60–I63 in any of the available diagnosis fields, between 1 January 2016 and 31 December 2023. Elective admissions were excluded to focus on acute stroke presentations, as were records missing the primary mortality outcome or missing HIV/stroke identification fields. The main cohort used an "any-listed" stroke definition (I60–I63 in any diagnosis field); a co-primary sensitivity cohort restricted to primary-diagnosis stroke (I60–I63 recorded as the principal diagnosis) was used to test the robustness of the outcome models to case definition.

The exposure of interest was HIV infection, ascertained by the presence of ICD-10-CM code B20 (HIV disease) or Z21 (asymptomatic HIV infection status) in any diagnosis field (code lists in Online Resource 1). The cohort was divided into two groups, stroke hospitalizations with HIV and stroke hospitalizations without HIV (Table 1).

Data were also collected on demographic, clinical, and hospital-level variables. Demographic features included age, sex, race/ethnicity, ZIP-code median household income national quartile, primary expected payer, hospital region, hospital bed size, hospital location/teaching status, and admission year. Comorbidity burden was summarized using the AHRQ-validated Elixhauser comorbidity software for ICD-10-CM, computed across all available diagnosis fields, and the continuous Elixhauser summary score was retained for adjustment. Clinical severity was additionally adjusted for using the All Patient Refined Diagnosis Related Group (APR-DRG) severity subclass, merged from the NIS Severity file.

Stroke subtype was derived from diagnosis-based code flags: hemorrhagic (I60 subarachnoid hemorrhage, I61 intracerebral hemorrhage, or I62 other/unspecified nontraumatic intracranial hemorrhage) and ischemic (I63 cerebral infarction); discharges with both a hemorrhagic and an ischemic code present were classified as overlapping ischemic/hemorrhagic. The ICD-10 code I64 (stroke not specified as hemorrhage or infarction) does not exist in ICD-10-CM and was therefore not used. A pandemic-era indicator classified discharge years 2016–2019 as pre-pandemic and 2020–2023 as pandemic-era, and concomitant COVID-19 infection was identified using ICD-10-CM code U07.1. Receipt of intravenous thrombolysis and mechanical thrombectomy was identified using ICD-10-PCS procedure codes (Online Resource 1).

Study outcomes

The primary outcome was in-hospital all-cause mortality, derived from the NIS DIED indicator and defined as death occurring during the hospitalization. Secondary outcomes included total hospital length of stay (LOS), measured in days from admission to discharge; hospitalization cost; and discharge disposition among patients discharged alive, collapsed into four mutually exclusive categories derived from DISPUNIFORM: routine discharge home (value 1); transfer to a short-term hospital (value 2); transfer to a skilled nursing, intermediate care or other facility, or discharge against medical advice (values 5 and 7); and home health care (value 6).

Hospitalization cost was derived by multiplying total charges by the NIS cost-to-charge ratio (CCR_NIS) for the corresponding year and is reported in nominal US dollars. Discharges with missing total charges or a missing cost-to-charge ratio were excluded from the cost analyses. Because total charges are stored under a different variable name in the 2023 file, unadjusted mean costs were calculated for 2023 discharges and the adjusted cost model for 2016–2022 discharges.

Statistical analysis

Descriptive statistics were used to characterize the study population by HIV status (stroke with HIV vs stroke without HIV). Continuous variables were presented as survey-weighted means with standard error (SE); categorical variables were presented as weighted counts and percentages. A design-based chi-square test with the Rao–Scott adjustment was used to compare categorical baseline characteristics and outcomes, accounting for the NIS complex survey design.

Temporal trends in the proportion of stroke hospitalizations occurring among patients with HIV were assessed using survey-weighted logistic regression of HIV status on admission year, modeled both as a continuous term and, separately, as a categorical factor. Because the NIS provides weighted discharge counts rather than a population denominator, the reported trend metrics are the weighted hospitalization volume and the HIV-positive proportion among stroke hospitalizations, not a population-based incidence rate.

For the primary outcome, multivariable survey-weighted logistic regression was used to examine in-hospital mortality (reported as adjusted odds ratio [aOR] with 95% CI), while length of stay and hospitalization cost were analyzed through survey-weighted linear regression (reported as beta coefficient with 95% CI). Discharge disposition among patients discharged alive was analyzed using survey-weighted multinomial logistic regression adjusted for age, sex, race/ethnicity and the Elixhauser index (reported as relative risk ratios [RRR]), with transfer to a skilled nursing, intermediate care or other facility, or discharge against medical advice, as the reference outcome. The mortality, length-of-stay and cost models were adjusted for age, sex, race/ethnicity, income quartile, primary payer, hospital region, hospital bed size, teaching status, admission year, the Elixhauser comorbidity index, and APR-DRG severity subclass. Because race/ethnicity and hospital region are not reported in the 2023 NIS file, all adjusted models, interaction models and the propensity-score analysis were estimated in 2016–2022 discharges with complete covariate data. Within the HIV-positive stroke population, logistic (mortality) and linear (length of stay) regression models additionally included receipt of intravenous thrombolysis and mechanical thrombectomy as predictors, alongside the same covariate set. The mortality and length-of-stay models were re-estimated within the primary-diagnosis stroke cohort as a sensitivity analysis.

As a prespecified exploratory analysis, effect modification of the HIV–mortality association by age, sex, race/ethnicity, hospital region, stroke subtype (ischemic vs hemorrhagic), and COVID-19 pandemic era was evaluated using joint Wald tests on the relevant interaction terms from the fully adjusted survey logistic model; the Holm step-down procedure was applied to control the family-wise error rate across the six exploratory interaction families. As a confirmatory check on the HIV effect for mortality and length of stay, 1:1 nearest-neighbor propensity-score matching was performed to estimate the average treatment effect on the treated, with the propensity model conditioning on age, sex, race/ethnicity, income quartile, and the Elixhauser index.

In accordance with HCUP data-use requirements, unweighted cell counts for HIV-positive subgroups were inspected before reporting any subgroup estimate, and any cell not meeting HCUP small-cell reporting thresholds was suppressed; strata containing no subpopulation members were omitted automatically by the survey estimator. The primary outcome was required to be complete for cohort inclusion; the extent of missingness for key model covariates was quantified before estimation, categorical covariates with missing values were handled per NIS convention, and complete-case survey estimation was used for all adjusted models, with the resulting analytic sample sizes reported in Online Resource 1.

A P value < .05 was considered statistically significant for all confirmatory analyses. All statistical analyses were performed using Stata (StataCorp, College Station, TX) with the survey estimation suite to account for the database's stratified, clustered design; Elixhauser comorbidities were computed using the elix22 package, and propensity-score matching was performed using teffects psmatch. All regression models incorporated NIS sampling weights to ensure nationally representative estimates. This study is reported in accordance with the RECORD extension of the STROBE statement for studies using routinely collected health data [17]; the completed checklist is provided as Online Resource 2.

Results

Study population

The analytic cohort was derived from 8 annual NIS files spanning discharge years 2016–2023 and comprised 706,824 unweighted hospitalizations with acute stroke, corresponding to an estimated 3,534,119 weighted hospitalizations. Of these, 3,906 unweighted hospitalizations (weighted n = 19,530) had HIV, accounting for 0.6% of acute stroke hospitalizations during the study period.

Baseline characteristics

Statistically significant differences were noted in all demographic categories (Table 1). Compared with acute stroke hospitalizations without HIV, hospitalizations in PLWH involved younger patients (mean age 55.7 years [SE 0.19] in PLWH vs 68.4 years [SE 0.003] without HIV), with a disproportionately higher share of males (70% vs 51%). Black patients made up 57% of PLWH hospitalizations compared with 18% of hospitalizations without HIV, whereas White patients made up 26% versus 65%, respectively. Hispanic patients also made up a higher percentage of HIV-positive hospitalizations than of hospitalizations without HIV, while Asian/Pacific Islander patients made up a smaller share.

ZIP-code median household income also differed significantly by HIV status: the lowest income quartile (Q1) comprised 8,820 (49%) HIV hospitalizations compared with 1,076,040 (31%) without HIV. Q2 comprised 4,270 (24%) HIV and 899,945 (26%) non-HIV hospitalizations, Q3 3,075 (17%) and 807,905 (23%), and Q4 1,785 (10%) and 671,790 (19%), respectively.

Hospital region differed significantly by HIV status (P < .001), with the South accounting for the most hospitalizations (1,320,155), including 9,235 (54%) HIV and 1,310,920 (42%) non-HIV hospitalizations for acute stroke. The Midwest followed with 658,770 hospitalizations, including 1,965 (11%) HIV and 656,805 (21%) non-HIV. The West accounted for 629,974 hospitalizations, including 2,130 (12%) HIV and 627,844 (20%) non-HIV. The Northeast accounted for the fewest weighted hospitalizations (536,695), with 3,875 (23%) among patients with HIV and 532,820 (17%) among those without HIV.

Hospital location/teaching status also differed significantly. Urban teaching hospitals carried most hospitalizations, particularly among HIV-positive patients (16,810 [86%] vs 2,649,980 [75%] without HIV).

Urban nonteaching (11% HIV vs 18% non-HIV) and rural (2% vs 7%) centers contributed the fewest hospitalizations.

Expected primary payer also differed significantly by HIV status. Medicare covered the most hospitalizations (2,170,619 weighted; 62%), representing 7,600 (39%) admissions in PLWH and 2,163,019 (62%) without HIV. Medicaid followed, covering 402,460 weighted hospitalizations (11%), including 6,275 (32%) in PLWH and 396,185 (11%) in those without HIV.

Hospital bed size also differed significantly between the 2 groups. Large hospitals accounted for the most weighted hospitalizations (1,937,881; 55%), with a similar distribution in both groups; medium-sized hospitals accounted for 5,885 (30%) HIV and 993,699 (28%) non-HIV hospitalizations, and small hospitals for 2,760 (14%) and 593,894 (17%), respectively.

Table 1
Baseline demographic, clinical, and hospital characteristics by HIV status (survey-weighted)

Characteristic	No HIV, n (%)	PLWH, n (%)	P value
Age, mean years (SE)	68.4 (0.003)	55.7 (0.19)	
Sex			< .001
Male	1,774,985 (51)	13,710 (70)	
Female	1,739,100 (49)	5,815 (30)	
Race/ethnicity			< .001
White	1,980,619 (65)	4,345 (26)	
Black	538,545 (18)	9,555 (57)	
Hispanic	294,950 (10)	2,165 (13)	
Asian/Pacific Islander	113,915 (4)	135 (1)	
Native American	14,960 (< 1)	85 (1)	
Other	91,220 (3)	580 (3)	
Primary payer			< .001
Medicare	2,163,019 (62)	7,600 (39)	
Medicaid	396,185 (11)	6,275 (32)	
Private insurance	697,360 (20)	3,740 (19)	
Self-pay	148,170 (4)	1,215 (6)	
No charge	11,290 (< 1)	55 (< 1)	
Other	92,550 (3)	600 (3)	
Median household income quartile (ZIP)			< .001
Q1 (lowest)	1,076,040 (31)	8,820 (49)	
Q2	899,945 (26)	4,270 (24)	
Q3	807,905 (23)	3,075 (17)	
Q4 (highest)	671,790 (19)	1,785 (10)	
Hospital location/teaching status			< .001
Rural	241,685 (7)	475 (2)	
Urban nonteaching	622,925 (18)	2,245 (11)	

Characteristic	No HIV, n (%)	PLWH, n (%)	P value
Urban teaching	2,649,980 (75)	16,810 (86)	
Hospital region			< .001
Northeast	532,820 (17)	3,875 (23)	
Midwest	656,805 (21)	1,965 (11)	
South	1,310,920 (42)	9,235 (54)	
West	627,844 (20)	2,130 (12)	
Hospital bed size			< .001
Small	593,894 (17)	2,760 (14)	
Medium	993,699 (28)	5,885 (30)	
Large	1,926,996 (55)	10,885 (56)	

PLWH, people living with HIV. SE, standard error. P values from survey-weighted Rao–Scott chi-square tests (categorical variables) or survey-weighted linear regression (age). Race/ethnicity and hospital region are not reported in the 2023 NIS; their distributions are based on 2016–2022 discharges.

Stroke subtypes

Stroke subtype distribution was similar in PLWH and people without HIV (Table 2). Among hospitalizations in PLWH, 62% were ischemic, 36% hemorrhagic, and 2% overlapping, compared with 60%, 37%, and 2%, respectively, among hospitalizations without HIV (P = .292).

Table 2
Stroke subtype by HIV status

Stroke type	No HIV, n (%)	PLWH, n (%)
Ischemic stroke	2,123,489 (60)	12,035 (62)
Hemorrhagic stroke	1,317,570 (37)	7,120 (36)
Overlapping stroke	73,530 (2)	375 (2)

PLWH, people living with HIV. P = .292 (survey-weighted Rao–Scott chi-square test).

Primary outcome: in-hospital mortality

In the adjusted survey-weighted model, HIV status was not independently associated with in-hospital mortality (aOR 0.94; 95% CI 0.84–1.06; P = .318). Age was independently associated with mortality, with each additional year conferring 1.5% higher odds of death (aOR 1.015; P < .001). Higher Elixhauser

comorbidity burden was associated with lower mortality odds in this model (aOR 0.89 per unit; P < .001), and hospital bed size and several payer categories were also independently associated with mortality.

Length of stay and hospitalization cost

Unadjusted mean LOS was 11.17 days with HIV versus 7.40 days without HIV. In the multivariable linear regression model adjusting for demographic, socioeconomic, hospital, clinical severity, and calendar-year characteristics, HIV status was not independently associated with LOS (coefficient − 0.32 days; 95% CI − 0.83 to 0.19; P = .221) (Table 3).

Among 2023 discharges, unadjusted mean hospitalization cost was $54,065 for hospitalizations with HIV compared with $34,683 for those without HIV. In the fully adjusted survey-weighted linear regression model (2016–2022 discharges with cost data; 519,140 unweighted hospitalizations), HIV status was associated with a $2,904 lower hospitalization cost (95% CI −$4,851 to −$958; P = .003) (Table 3).

Table 3
Length of stay and hospitalization cost by HIV status

Outcome	Adjusted effect estimate, HIV vs no HIV (95% CI)	Unadjusted means, HIV vs no HIV	P value
Length of stay, days	−0.32 (− 0.83 to 0.19)	11.17 vs 7.40 days	.221
Hospitalization cost, US$	−2,904 (− 4,851 to − 958)	$54,065 vs $34,683 (2023)	.003

CI, confidence interval. Adjusted estimates are survey-weighted linear regression coefficients for HIV vs no HIV (2016–2022 discharges); cost is in nominal US dollars, and unadjusted mean cost is for 2023 discharges.

Discharge disposition and reperfusion therapy

Among patients discharged alive, discharge disposition differed significantly by HIV status (P = .001; Table 4). Among survivors with HIV, 37% were discharged routinely home, 4% were transferred to a short-term hospital, 45% were transferred to a skilled nursing, intermediate care or other facility or left against medical advice, and 14% were discharged with home health care, compared with 34%, 4%, 45%, and 16%, respectively, among survivors without HIV.

In adjusted multinomial logistic regression (reference: transfer to a skilled nursing, intermediate care or other facility, or discharge against medical advice), HIV-positive status was associated with a higher relative likelihood of routine discharge home (RRR 1.14; 95% CI 1.05–1.25; P = .004), but not with transfer to a short-term hospital (RRR 0.87; 95% CI 0.72–1.06; P = .176) or discharge with home health care (RRR 1.03; 95% CI 0.92–1.16; P = .563).

Table 4
Discharge disposition by HIV status among patients discharged alive

Discharge disposition	No HIV, n (%)	PLWH, n (%)
Routine discharge home	1,067,320 (34)	6,365 (37)
Transfer to short-term hospital	123,520 (4)	700 (4)
Transfer to SNF, ICF or other facility, or against medical advice	1,412,245 (45)	7,685 (45)
Home health care	513,465 (16)	2,485 (14)

Hospitalizations discharged alive with a known disposition. ICF, intermediate care facility; PLWH, people living with HIV; SNF, skilled nursing facility. P = .001 (survey-weighted Rao–Scott chi-square test).

Within the HIV-positive cohort, neither intravenous thrombolysis (OR 0.75; 95% CI 0.39–1.46; P = .396) nor mechanical thrombectomy (OR 1.06; 95% CI 0.47–2.42; P = .885) was significantly associated with in-hospital mortality. Intravenous thrombolysis was associated with a 1.85-day shorter length of stay (95% CI − 3.30 to − 0.40; P = .012), whereas thrombectomy was not significantly associated with length of stay (2.92 days; 95% CI − 1.04 to 6.87; P = .148). No individual calendar year from 2017 through 2022 was significantly associated with mortality in this model.

Subgroup analyses and effect modification

Interaction terms (HIV × subgroup variable) were tested for the primary mortality outcome across age, sex, race/ethnicity, hospital region, COVID-19 period, and stroke subtype (Table 5).

A statistically significant interaction between HIV status and age was observed (interaction OR 0.983 per year; 95% CI 0.973–0.993; P = .001; joint Wald test P = .0006), indicating that the association between HIV and mortality varied with patient age; this interaction remained significant after Holm correction (Holm-adjusted P = .004). There was no evidence of effect modification by sex (interaction OR 1.16; 95% CI 0.90–1.51; P = .253), race/ethnicity (joint Wald test P = .405), hospital region (joint Wald test P = .695), or stroke subtype (interaction OR for hemorrhagic vs ischemic stroke 1.19; 95% CI 0.93–1.52; P = .175). The pandemic period also showed no significant interaction with HIV status (interaction OR 1.16; 95% CI 0.91–1.47; joint Wald test P = .237).

Table 5
Subgroup-specific HIV–mortality associations and tests for interaction

Subgroup variable	Reference-group HIV aOR (95% CI)	Interaction OR (95% CI)	P value	Holm-adjusted P
Sex (ref: male)	0.90 (0.79–1.04)	1.16 (0.90–1.51)	.253	.949
Age (per year)	Not reported	0.98 (0.97–0.99)	.001	.004
Race/ethnicity (ref: White)	0.81 (0.64–1.02)	Black 1.28 (0.97–1.70); Hispanic 1.16 (0.78–1.70); Asian/Pacific Islander 0.91 (0.29–2.81); Native American 0.29 (0.04–2.30); Other 1.27 (0.70–2.30)	.405	.949
Hospital region (ref: Northeast)	0.96 (0.73–1.28)	Midwest 1.08 (0.69–1.66); South 0.92 (0.66–1.27); West 1.08 (0.73–1.62)	.695	.949
Stroke subtype (ref: ischemic)	0.94 (0.77–1.14)	Hemorrhagic 1.19 (0.93–1.52)	.175	.875
Calendar era, 2020+ (ref: pre-2020)	0.89 (0.76–1.03)	1.16 (0.91–1.47)	.237	.949

aOR, adjusted odds ratio; CI, confidence interval; OR, odds ratio. The reference-group HIV aOR is the HIV–mortality association in the reference category; for age, the interaction OR is per additional year. P values are from Wald tests of the interaction terms (joint tests for multi-category variables); Holm-adjusted P values account for the six prespecified interaction families.

Temporal trends, 2016–2023

The weighted prevalence of HIV among stroke hospitalizations showed no significant temporal trend (OR per year 1.011; 95% CI 0.995–1.023; P = .186). When calendar year was modeled categorically, there was likewise no significant overall difference across years (F = 0.74; P = .642) (Table 6).

Table 6
Temporal trends in concurrent HIV among stroke hospitalizations, 2016–2023

Year	OR for HIV (95% CI)	P value
2016	1.00 (reference)	—
2017	1.06 (0.92–1.22)	.428
2018	0.96 (0.83–1.11)	.578
2019	1.05 (0.90–1.22)	.568
2020	1.02 (0.88–1.19)	.783
2021	1.02 (0.88–1.18)	.764
2022	1.06 (0.91–1.23)	.449
2023	1.12 (0.97–1.30)	.133
Overall categorical year effect	—	**.642**
Linear trend per year	**1.01 (0.995–1.023)**	**.186**

CI, confidence interval; OR, odds ratio. Unadjusted survey-weighted logistic regression of HIV status on admission year.

Propensity score–matched sensitivity analysis

A propensity score for HIV was estimated via logistic regression on the demographic and comorbidity covariate set. Matching (1:1 nearest neighbor) was performed among 599,977 hospitalizations with complete covariate data (Table 7). The estimated average treatment effect on the treated (ATET) for HIV status was − 0.0083 (SE 0.0062; 95% CI − 0.0205 to 0.0039; P = .182), indicating no statistically significant difference in in-hospital mortality between stroke hospitalizations with and without HIV after matching. Similarly, HIV status was not significantly associated with LOS after matching (ATET − 0.31 days; 95% CI − 0.89 to 0.28; P = .309).

Table 7
Propensity score–matched analysis of in-hospital mortality and length of stay by HIV status

Outcome	N (unweighted)	ATET, HIV vs no HIV	Robust SE	95% CI	P value
In-hospital mortality (absolute risk difference)	599,977	−0.0083	0.0062	−0.0205 to 0.0039	.182
Length of stay, days	599,933	−0.31	0.30	−0.89 to 0.28	.309

ATET, average treatment effect on the treated; CI, confidence interval; SE, standard error. Estimates from 1:1 nearest-neighbor propensity-score matching with replacement (Stata teffects psmatch); the logit

propensity model conditioned on age, sex, race/ethnicity, ZIP-code income quartile and the Elixhauser index. Ties were retained (maximum 534 matches per hospitalization), and SEs are Abadie–Imbens robust. Matching used unweighted 2016–2022 discharges with complete covariate data. For mortality, the ATET is the difference in the probability of in-hospital death (− 0.0083 = − 0.83 percentage points).

Primary-diagnosis stroke sensitivity analysis

In a sensitivity analysis restricted to hospitalizations with stroke as the principal diagnosis, HIV was associated with lower odds of in-hospital mortality in the fully adjusted survey-weighted logistic regression model (OR 0.74; 95% CI 0.61–0.90; P = .003). This finding differed from the main analysis of the broader stroke cohort, in which HIV status was not significantly associated with mortality (aOR 0.94; P = .318).

Discussion

In this nationally representative analysis of an estimated 3.53 million acute stroke hospitalizations between 2016 and 2023, PLWH accounted for a small but stable 0.6% of the inpatient stroke burden. Stroke hospitalizations in PLWH involved younger patients, who were predominantly male, Black, Medicaid-insured, resident in the lowest-income ZIP codes, located in the South, and treated in urban teaching hospitals. Despite a crude length of stay about 50% longer and crude costs about 56% higher, HIV was not independently associated with in-hospital mortality or length of stay. HIV was associated with modestly lower cost and, among principal-diagnosis strokes, with lower adjusted odds of death. The HIV–mortality association weakened with each additional year of age. These findings suggest that in the ART era, the excess inpatient burden of stroke in PLWH is driven mainly by patient demographics, social disadvantage and complex care needs rather than by an intrinsic HIV-related increase in in-hospital lethality.

Stable stroke burden after two decades of growth

The flat HIV proportion across 2016–2023 contrasts with earlier NIS analyses. Between 1997 and 2006, stroke hospitalizations among PLWH rose by about two-thirds while those in the general population fell by 7% [18], and from 2002 to 2012 HIV-associated stroke admissions continued to grow faster than stroke admissions overall [19]. Our data suggest that this growth has plateaued. A plausible explanation is the maturation of the US epidemic: the number of people with diagnosed HIV has grown only slowly, to about 1.16 million by the end of 2024, but the population has aged, and those aged 55–64 years are now the largest single group [20]. Ageing would be expected to raise stroke counts, whereas near-universal ART and higher rates of viral suppression should reduce strokes driven by immunosuppression and uncontrolled viremia, both of which predict stroke incidence [8, 21]. The 0.6% we observed is close to the 0.7% (24 of 3,615) reported among acute ischemic stroke patients in a German stroke-unit cohort in which most PLWH were receiving ART with undetectable viral loads [22]. Because the NIS has no population denominator, this stability describes the share of hospital stroke burden, not incidence; meta-

analyses continue to show that PLWH carry a higher per-person risk of both ischemic and hemorrhagic stroke [5, 6].

A younger, socially disadvantaged population

PLWH in our cohort were hospitalized for stroke at a mean age of about 56 years, compared with about 68 years for those without HIV. This gap matches the 52 versus 70 years reported in earlier NIS data [19], the mean age of 54 years in the German ART-treated cohort [22], and recent syntheses showing that stroke in PLWH occurs at a substantially younger age than in the general population [23]. In a large US health-system cohort, the relative excess of ischemic stroke with HIV was greatest at 18–29 years (incidence rate ratio 4.4) and declined progressively with age, with the excess largely confined to adults younger than 50 years [8]; HIV-associated intracerebral hemorrhage showed the same age gradient [24].

The demographic signature of HIV-associated stroke has proven remarkably durable. A decade ago, 56–58% of HIV-associated stroke hospitalizations involved Black patients, about half were treated in the South, and roughly one-third were covered by Medicaid [19]; our estimates for 2016–2023 are nearly identical. Male representation parallels the US HIV epidemic (70% vs 77%), whereas Black representation exceeds their share of people with diagnosed HIV (39%), potentially compounding their existing stroke burden and earlier onset [20, 25]. Nearly half of PLWH with stroke lived in the lowest income quartile, and 86% were treated in urban teaching hospitals, where HIV specialty care is concentrated. HIV-associated stroke therefore sits at the intersection of two epidemics that cluster in largely Southern and Black communities, which is where prevention and post-stroke resources should be directed.

In-hospital mortality

The absence of an independent association between HIV and in-hospital mortality (aOR 0.94; 95% CI 0.84–1.06) is consistent with the most directly comparable US evidence. In NIS data from 2002–2012, patients with a history of AIDS had more than twice the odds of in-hospital death after stroke (OR 2.59), whereas HIV-infected patients without AIDS had no significant excess [19]. The same split has been reported after acute myocardial infarction (AMI) treated with percutaneous coronary intervention, where symptomatic HIV carried a 3.6-fold higher in-hospital mortality and asymptomatic HIV carried none [26], and contemporary NIS analyses of coronary bypass surgery and of AMI management have found largely similar in-hospital outcomes for PLWH [27, 28]. Prospective data from Cameroon similarly show longer stays and more post-stroke infections in PLWH, but similar 6-month mortality and functional outcomes [29].

As ART has moved most US PLWH away from advanced immunosuppression, the population hospitalized with stroke now resembles the "HIV without AIDS" group of earlier studies. Immune status, rather than serostatus itself, appears to be the main determinant of risk: CD4 counts below 200 cells/μL and higher viral loads predict stroke incidence and plausibly prognosis [8, 21]. Because our exposure pooled B20 (HIV disease) with Z21 (asymptomatic HIV status), a smaller high-risk subgroup with advanced disease may be diluted within a reassuring overall estimate.

Two findings warrant interpretation. First, among principal-diagnosis strokes, HIV was associated with 26% lower adjusted odds of death. Black patients, who comprised most of the HIV cohort, have lower in-hospital stroke mortality than White patients, partly due to more frequent life-sustaining interventions and substantially lower hospice discharge rates (OR 0.25) [30]. The NIS records neither do-not-resuscitate status nor stroke severity, leaving both as potential confounders.

Second, the difference between the any-listed and principal-diagnosis cohorts is informative. An any-listed definition also captures strokes that complicate admissions for another illness, and in-hospital–onset strokes are treated later and have worse outcomes than community-onset strokes [31]. In PLWH, such strokes may more often arise during admissions for sepsis, opportunistic infection or coagulopathy [10, 23]. A null association in the broad cohort alongside a protective one in principal-diagnosis strokes implies that HIV may carry relatively higher risk among strokes that complicate other admissions. However, this sensitivity-analysis finding is hypothesis-generating and warrants formal testing using an HIV × diagnosis-position interaction.

Age modifies the HIV–mortality association

An approximately 1.7% decline in the HIV–mortality odds ratio per additional year of age indicates that any mortality disadvantage linked to HIV is concentrated in younger patients and diminishes with age. This parallels findings in which the HIV-attributable excess of both ischemic stroke and intracerebral hemorrhage is greatest in young adults and diminishes with age [8, 24]. The biology is plausible. Strokes in younger PLWH are more often driven by HIV-specific mechanisms, including HIV-associated vasculopathy, infectious vasculitis (varicella-zoster virus, syphilis, tuberculosis, and cryptococcus), immune reconstitution inflammatory syndrome, coagulopathy, and substance use, whose course differs from that of conventional atherosclerotic or cardioembolic stroke [4, 9, 10, 23]. In older PLWH, stroke increasingly resembles age-related vascular disease, and age-related competing risks dominate outcomes.

Clinically, this supports a lower threshold for an expanded etiological work-up in young PLWH with stroke, including CD4 count, viral load and screening for syphilis and other relevant coinfections, as recently recommended [23].

Stroke subtype

The subtype distribution did not differ by HIV status (about 60–62% ischemic and 36–37% hemorrhagic in both groups). This contrasts with a cohort study showing that HIV increases the risk of intracerebral hemorrhage, particularly at CD4 counts below 200 cells/μL [24], and with meta-analytic evidence of excess hemorrhagic as well as ischemic stroke in PLWH [5, 6]. This likely reflects the hospital-based denominator, as proportional increases in both subtypes preserve their admission proportions. The hemorrhagic share in both groups is also higher than usually reported.

Length of stay, cost and discharge disposition

The crude excess in length of stay (11.2 vs 7.4 days) and cost ($54,065 vs $34,683 in 2023) disappeared after adjustment, with modestly lower adjusted costs in PLWH (−$2,904). Earlier NIS data showed the same pattern: stroke admissions were about 30% longer in patients with a history of AIDS but slightly shorter in those without AIDS [19], and excess resource use after AMI was likewise confined to symptomatic HIV [26].

The lower adjusted cost may reflect lower procedural intensity, including reperfusion. PLWH with stroke are concentrated in groups, including Black, Medicaid-insured and socially vulnerable patients, that are less likely to receive thrombectomy and thrombolysis [32, 33], so reporting reperfusion rates by HIV status is an important next step. The higher likelihood of routine discharge home rather than transfer to a post-acute facility among surviving PLWH is consistent with their younger age, whereas earlier data showed modestly more institutional discharge among PLWH without AIDS [19]. Whether lower use of post-acute facilities reflects better recovery or poorer access to rehabilitation for Medicaid and uninsured patients cannot be determined from administrative data.

Reperfusion therapy in PLWH

Within the HIV cohort, neither intravenous thrombolysis (IVT) nor thrombectomy was significantly associated with in-hospital mortality, and IVT was associated with a shorter length of stay. Evidence on reperfusion in PLWH remains limited. In a multicenter US series, IVT in PLWH produced no fatalities and a 6% rate of hemorrhagic transformation [34]. A 2026 review concluded that reperfusion appears feasible in clinically stable HIV but that the evidence mostly reflects well-controlled disease, and that caution is warranted where infectious vasculitis is suspected [23]. HIV infection is not among the contraindications to IVT in current AHA/ASA guidance [35].

These findings should be interpreted cautiously, and the wide confidence intervals reflect small numbers. IVT recipients are selected for early presentation, smaller deficits and the absence of contraindications such as active infection or coagulopathy, so confounding by indication is likely; thrombectomy is reserved for large-vessel occlusion, which carries a higher baseline mortality. IVT capture in the NIS also changed at the ICD-10 transition, and patients thrombolysed before transfer may be missed, so under-ascertainment is possible [36, 37]. Our results do not suggest that HIV status should lead clinicians to withhold reperfusion from otherwise eligible patients.

The COVID-19 pandemic

The pandemic did not modify the HIV–mortality association (interaction OR 1.16; P = .24), and the HIV share of stroke hospitalizations did not change after 2019. The pandemic disrupted stroke systems and delayed presentation [12–14], and in-hospital ischemic stroke mortality in the NIS increased in 2020, driven largely by COVID-19 coinfection, with the steepest increases among Hispanic and lowest-income patients [38]. HIV care was disrupted through fewer visits, less viral-load monitoring and interrupted ART access [39], and PLWH had higher odds of COVID-19 death in both US and global data (aOR 1.29 and aHR 1.38) [40, 41].

Our null interaction suggests broadly similar in-hospital stroke outcomes for PLWH across eras. However, because 2023 discharges lacked race and region data, the adjusted pandemic-era indicator covered 2020–2022 and includes post-vaccine years, the point estimate exceeded 1, and the interaction test was underpowered. Restricting analyses to 2020–2021 or to PLWH with concurrent COVID-19 may provide more sensitive tests.

Clinical implications and future directions

Three implications follow. First, HIV serostatus alone should not drive prognostic pessimism or decisions about acute treatment; immune status and stroke mechanism matter more [19, 23]. Second, because PLWH have strokes more than a decade earlier and are concentrated in disadvantaged communities, prevention must start earlier and reach the populations most affected. In the REPRIEVE trial, pitavastatin reduced major adverse cardiovascular events by 35% in PLWH at low-to-moderate predicted risk [42], and AHA guidance calls for intensive management of traditional risk factors, noting that standard risk calculators underestimate risk in PLWH [1].

Third, several questions can now be answered with linked data. Priorities include linking inpatient records to CD4 count, viral load and ART exposure; stratifying analyses by B20 versus Z21; obtaining stroke severity and functional outcomes from registries such as Get With The Guidelines–Stroke; following readmission and post-discharge mortality in the Nationwide Readmissions Database; and studying reperfusion use and safety in PLWH directly, including in the youngest patients, in whom HIV-specific mechanisms predominate.

Strengths and limitations

This study has several strengths. It is, to our knowledge, the largest contemporary national analysis of stroke hospitalizations in PLWH and the first to span the entire ICD-10-CM era, including the COVID-19 pandemic. Variance estimation used year-specific strata and hospital clusters, and the main findings were tested with propensity-score matching, an alternative principal-diagnosis case definition and Holm-corrected interaction tests.

Several limitations should be considered. First, HIV and stroke were identified from administrative codes; HIV is likely under-coded, which would misclassify some PLWH as uninfected and bias estimates toward the null, and pooling B20 with Z21 obscures disease stage. Second, the NIS lacks CD4 count, viral load, ART exposure, stroke severity (NIHSS), imaging, stroke etiology and do-not-resuscitate status, so residual confounding is likely. Third, the unit of analysis is the discharge rather than the patient, so transfers and readmissions may be counted more than once. Fourth, outcomes are limited to the index hospitalization, with no information on post-discharge mortality or functional recovery.

Fifth, IVT is incompletely captured in ICD-10-PCS data, and reperfusion analyses within the HIV cohort were limited by small numbers and HCUP small-cell rules [36, 37]. Sixth, cost was estimated from charges with cost-to-charge ratios, was not inflation-adjusted, and the unadjusted and adjusted cost estimates came from different years (2023 and 2016–2022, respectively); in addition, race/ethnicity and

hospital region are not reported in the 2023 NIS, so adjusted analyses excluded 2023 discharges. Seventh, adjustment for APR-DRG severity, which incorporates HIV-related diagnoses, may have over-adjusted the HIV estimates. Finally, the design is cross-sectional, so associations cannot be interpreted causally.

Conclusions

Across US hospitals from 2016 to 2023, PLWH accounted for a stable 0.6% of acute stroke hospitalizations and were markedly younger, more often Black, Southern, low-income and Medicaid-insured than patients without HIV. After accounting for these differences, HIV was not independently associated with higher in-hospital mortality, longer length of stay or higher cost, and reperfusion was not associated with excess mortality among PLWH. The HIV–mortality association weakened with age, suggesting that the youngest PLWH, in whom HIV-specific stroke mechanisms are most common, warrant particular attention. Reducing the stroke burden in PLWH will therefore depend less on in-hospital care than on earlier, targeted prevention, sustained viral suppression and equitable access to acute stroke services.

Declarations

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Code availability: Stata do-files are available from the corresponding author on reasonable request.

Use of large language models: Claude (Anthropic) was used to assess the manuscript before submission. Claude built table 7 of the manuscript and corrected the population number which was written as roughly 3900 to 3906 which is precise. The author then assessed the manuscript and takes full responsibility.

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