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Geographic disparities in late HIV diagnoses in Tennessee: Opportunities for interventions in the rural Southeast

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Abstract

Purpose: Incident HIV remains an important public health issue in the U.S. South, the region leading the nation in HIV incidence, rural HIV cases, and HIV-related deaths. Late diagnoses drive incident HIV and understanding factors driving late diagnoses is critical for developing locally relevant HIV testing and prevention interventions, decreasing HIV transmission, and ending the HIV epidemic.

Methods: Retrospective cohort study utilizing Tennessee Department of Health (TDH) surveillance data and U.S. Census Bureau data. Adults ≥18 years old with a new HIV diagnosis between January 1, 2015 and December 31, 2019 identified in the TDH eHARS were included. Individuals were followed from initial HIV diagnosis until death, 90 days of follow-up for outcome assessment, or administrative censoring 90 days after study enrollment closed.

Findings: We included 3,652 newly HIV-diagnosed individuals; median age was 31 years (IQR: 25, 42), 2909 (79.7%) were male, 2057 (56.3%) were Black, 246 (6.7%) were Hispanic, 408 (11.2%) were residing in majority-rural areas at diagnosis, and 642 (17.6%) individuals received

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Conflicts of Interest

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a late HIV diagnosis. Residents of majority-rural counties (aRR=1.39, 95% CI: 1.16–1.67) and Hispanic individuals (aRR=1.87, 95% CI: 1.50–2.33) had an increased likelihood of receiving a late diagnosis after controlling for race/ethnicity, age, and year of HIV diagnosis.

Conclusions: Rural residence and Hispanic ethnicity were associated with an increased risk of receiving a late HIV diagnosis in Tennessee. Future HIV testing and prevention efforts should be adapted to the needs of these vulnerable populations.

Keywords

HIV; AIDS; Late HIV diagnoses; Rural health; Rural-urban disparities

Background

Delays in HIV diagnosis and treatment initiation are important public health problems which present barriers to ending the HIV epidemic. This is especially salient in the Southern United States (U.S.), including Tennessee, as the region accounts for 52% of new HIV cases, 50% of undiagnosed HIV infections, and 47% of HIV-related deaths despite representing only 38% of the U.S. population.[1,2] Urban areas account for a majority of HIV diagnoses in the South; however, this region is unique as it has the highest proportion of rural HIV diagnoses in the nation (~24%).[3] Over 20% of HIV diagnoses in the South are considered "late"— defined as having a stage-3 HIV (AIDS) diagnosis within 90 days of initial HIV diagnosis.[4] In 2019, Tennessee had the 14th highest incidence of stage-3 HIV diagnoses in the US and a late diagnosis proportion of ~17%.[5,6] Identifying distinctive challenges and needs of Southern communities is essential for developing interventions to address delays in HIV diagnoses.

Limited studies examine predictors of late HIV diagnoses, particularly in the rural South. These studies suggest older age, racial/ethnic minority status (particularly Hispanic men who have sex with men [MSM]), non-metropolitan residence, further distance from HIV testing sites, and being uninsured are risk factors for late HIV diagnosis.[7– 10] Given the unique epidemiologic profile of HIV in the South, as well as the clinical and public health implications of late HIV diagnoses, further investigations examining factors affecting HIV health outcomes in the region are needed to optimize HIV testing and prevention programs. This is critical in Tennessee as state officials recently announced significant funding changes for HIV testing and prevention services, declining nearly $9 million in federal funding for these services by ending two large Centers for Disease Control and Prevention (CDC) grants.[11]

Identifying populations disproportionately affected by late HIV diagnoses despite existing resources is crucial for guiding resource allocation for these groups during HIV-related program development, developing locally relevant and contextually appropriate HIV screening and prevention initiatives, and engaging appropriate community partners. This study fills key gaps in ethnographic data which will add to our understanding of groups at risk for late HIV diagnoses in the rural South and contextualize potential implications of recently announced changes to HIV testing and prevention funding and priority populations in Tennessee.

Methods

Study Population and Follow-up

Individuals aged ≥18 years with a new diagnosis of HIV between January 1, 2015, and December 31, 2019, in the Tennessee Department of Health (TDH) electronic HIV/AIDS Reporting System (eHARS) were included. Individuals were followed from date of HIV diagnosis until death, 90 days after enrollment, or until 90 days after all study enrollment closed (i.e., March 31, 2020), so all individuals had equivalent etiologically relevant risk periods for the outcome.

Data Collection and Study Definitions

Exposure of interest—Population density and rural-urban determinations, including proportion of a county considered rural, were obtained from the 2010 U.S. Census Bureau data for all 95 counties in Tennessee. Majority-rural status was defined as ≥50% of housing clusters in areas with <2,500 individuals or sub-urban population density of <1,000 people/square mile.[12] Individual exposure status, either majority-rural status (dichotomous) or proportion rural (continuous), was assigned by self-reported county of residence at HIV diagnosis. “Majority” rural definitions and cut offs were used for this study as the Tennessee Department of Health, local health departments, and government funding agencies have a vested interest in classifying areal units (counties) as “majority” rural vs. not for the purposes of public health programing and funding allocation.

Outcome of interest—Data regarding stage 3 HIV diagnoses were collected from eHARS by “immunologic criteria” (CD4 count <200 or a CD4% <14) and “clinical criteria” (an AIDS defining illness). Late HIV diagnosis, the dichotomous primary outcome of interest, was determined as having a stage 3 HIV diagnosis by either immunologic or clinical criteria ≤90 days after HIV diagnosis or not.

Covariates and potential confounders—Demographic information, vital status, HIV acquisition risk factors, and HIV-related laboratory results were obtained from TDH eHARS. Age in years was defined as age at first recorded positive HIV test. Racial and ethnic data were self-reported as “Black non-Hispanic”, “White non-Hispanic”, “Hispanic”, or “Other/Unknown”. Gender identity was self-reported as “cisgender male”, “cisgender female”, and “transgender person”. HIV acquisition risk factor was self-categorized as “MSM”, “Persons Who Inject Drugs (PWID)”, “Heterosexual Contact”, and “Other/Unknown”. Self-reported county of residence at HIV diagnosis was used to determine Tennessee Public Health Region, geographic divisions comprised of ≥1 counties and used for public health planning, funding, and program development. Six regions (Madison, Shelby, Knox, Davidson, Hamilton, and Sullivan regions) are comprised entirely of urban areas; the remaining seven regions (West, South Central, Mid Cumberland, Upper Cumberland, Southeast, East, and Northeast regions) are comprised of rural and urban areas.[13] Vital status and date of death were verified via National Death Index, Social Security Death Master File, and Tennessee Vital Statistics death records.

County-level data for insurance status, educational attainment, and poverty were obtained from the U.S. Census Bureau's 2016–2020 American Community Survey (ACS). Insurance status was defined as the proportion of individuals within a county without health insurance. Educational attainment was defined as the proportion of individuals ≥25 years old in a county who either: (1) had not completed high school, (2) were high school graduates but had not attended college, or (3) had at least some college education. Poverty was defined as the proportion with incomes below the federal poverty threshold as defined by the U.S. Census Bureau.[14] Individuals were assigned these contextual variable values by their county of residence at HIV diagnosis.

Statistical Analyses—Differences in late HIV diagnosis outcomes by individual characteristics were described using χ^2 (categorical variables) and Kruskal-Wallis (continuous variables) tests. Multivariable modified Poisson regression models were used to estimate adjusted risk ratios (aRR) and associated 95% confidence intervals (CI) of late HIV diagnosis by county-level rurality. We modeled the proportion rural continuously using restricted cubic splines with 3 knots. Covariates in adjusted models were selected *a priori* using a conceptual framework (Figure 1) and included age, race/ethnicity, and year of HIV diagnosis.[15] Additional analyses adjusted for county-level educational attainment, poverty, and insurance status context; we assessed county-level variables for collinearity with proportion rural using the Pearson ρ (rho) coefficient for continuous measures. Two-way interactions between race/ethnicity and both late HIV diagnosis and majority urban/majority rural county of residence were assessed. Missing data for HIV acquisition risk factor (>10%) were imputed ten times using multiple imputation by chained equations; all other covariates had missingness <1%, and were excluded if missing.[16,17] Analyses were conducted using STATA 17.0 (Stata Corp, College Station, TX).[18]

Results

Population & Baseline Characteristics

We included 3,652 individuals with newly diagnosed HIV in Tennessee (Table 1); median age was 31 years (IQR: 25, 42), 79.7% were cisgender male, 56.3% were non-Hispanic Black, 53.4% were MSM, 88.8% were diagnosed in majority-urban counties, and 17.6% received a late HIV diagnosis. Late HIV diagnosis occurred for 16.6% and 25.2% among majority-urban and majority-rural counties, respectively ($p<0.001$). In majority-rural counties, 27.2% of newly diagnosed individuals were non-Hispanic Black, 64.2% were non-Hispanic White, and 6.4% were Hispanic; in majority-urban counties, 60.0% were non-Hispanic Black, 30.2% were non-Hispanic White, and 6.8% were Hispanic ($p<0.01$).

Geographic Distribution of Late HIV Diagnoses in Tennessee

Public health regions in Eastern Tennessee had the highest proportion of late HIV diagnoses occurring in majority-rural areas in the state (Figure 2). Of the six TDH public health regions comprised exclusively of urban areas, only the Sullivan/Blountville public health region in Eastern Tennessee had a late HIV incidence of >20% (26.5%). In contrast, five of seven public health regions comprised of both rural and urban areas had proportions of late HIV diagnoses >20%.

Primary Outcome: Risk of Receiving a Late HIV Diagnosis in Tennessee

Individuals residing in majority-rural counties in Tennessee (vs. majority-urban) at HIV diagnosis were at increased risk of receiving a late HIV diagnosis (crude RR=1.52, 95% CI: 1.27–1.83; Figure 3, Supplementary Table 1). This increased risk persisted after adjusting for individual race/ethnicity, age, and year of HIV diagnosis (aRR=1.39, 95% CI: 1.16–1.67). When additionally adjusting for county-level contextual variables including insurance status, educational attainment, and poverty the increased risk of receiving a late HIV diagnosis among individuals residing in rural areas was attenuated and no longer statistically significant, though the direction of effect remained consistent (aRR=1.14, 95% CI: 0.79–2.33). Assessing for multicollinearity in the model, we found that poverty (ρ=0.37) and uninsured status (ρ=0.46) were moderately correlated with rurality, and that educational attainment was highly correlated (ρ=0.92).

The adjusted risk of receiving a late HIV diagnosis was highest among Hispanic individuals residing in rural counties (vs. non-Hispanic Black individuals; aRR=1.90, 95% CI: 1.54–2.36). We found no statistically significant interaction between race/ethnicity and late HIV diagnoses (p=0.718) or majority urban/majority rural county of residence at the time of initial HIV diagnosis (p=0.182).

When modeling the proportion rural of each county, the risk of receiving a late HIV diagnosis increased with increasing rurality (Figure 4, Supplementary Table 2). Analyses adjusted for age, race/ethnicity, year of HIV diagnosis and county-level insurance status, educational attainment, and poverty and demonstrated a clear increase in the risk of late HIV diagnosis as the proportion rural of a county increased; from a risk of ~11% among individuals residing in very low rurality counties (proportion rural = 2.5%) to >20% in moderately rural counties (proportion rural = 40%). This is demonstrated by steadily increasing risk ratios, comparing those in areas which were 20% (aRR=1.51; 95% CI: 1.12–2.04), 40% (aRR=1.94; 95% CI: 1.27–2.95), 60% (aRR=2.21; 95% CI: 1.36–3.61), and 80% (aRR=2.50; 95% CI: 2.38–4.51) rural to areas which were only 2.5% rural (Figure 4, Supplementary Table 2).

Discussion

Among individuals newly diagnosed with HIV in Tennessee between January 1, 2015, and December 31, 2019, the risk of receiving a late HIV diagnosis was higher for individuals residing in majority-rural (vs. majority-urban) counties even after controlling for individual-level age, race/ethnicity, and year of HIV diagnosis, though not significantly after adjusting for county-level contextual factors including poverty, educational attainment, or uninsured status. We found that these county-level factors are strongly collinear with county rurality, making it plausible that they are actually mediators of the rurality-late diagnosis relationship, in which case, the adjusted estimate reflects the remaining “direct effect” of county rurality on late diagnosis *not* mediated through county-level factors. This would explain the attenuated effect size and loss of significance when adjusting for these contextual variables. We also found that the risk of receiving a late HIV diagnosis increased with increasing rurality. Late HIV diagnoses were not homogenously distributed across Tennessee. Exclusively urban public health regions tended to have lower rates of late HIV

diagnoses than those including more rural areas, with public health regions in more rural Eastern Tennessee having the highest incidence of late HIV diagnoses.

These data corroborate other studies demonstrating rural residence as a significant risk factor for receiving a late HIV diagnosis.[19–23] This is important as the South has the highest incidence of rural HIV diagnoses, and rural communities face unique challenges regarding HIV testing and prevention.[24] One challenge is access to health care providers and services limited in rural areas. As a result, individuals in rural areas may have to travel significant distances to access care—particularly specialty care, including HIV testing and prevention services.[25–27] One study found the median national county-level drive time to HIV care for rural counties is ≥2 times urban counties (90 vs. 40 minutes). This study also estimated geographic access to HIV-related services was suboptimal for >170,000 people with HIV (19% of all people with HIV), over half which reside in the South with rural Southern communities being disproportionately affected.[25] Another study found >80% of Southern counties lacked an HIV-experienced provider.[28] The lack of convenient health care infrastructure in rural areas introduces numerous barriers for rural residents seeking HIV-related services such as the cost and availability of transportation and financial concerns regarding missed work. These challenges highlight the importance of investing in alternative, more accessible HIV testing interventions that have shown promise, including the use of mobile applications to connect individuals to HIV testing/prevention services, mobile HIV testing/prevention, telemedicine services, home HIV testing, and partnering with syringe service programs/medication-assisted treatment programs.[29–37]

Another barrier driving high rates of late HIV diagnoses in the rural South is the failure of many Southern states to expand Medicaid under the Affordable Care Act (ACA). Medicaid expansion results in increased rates of HIV testing and diagnoses, particularly in rural areas, areas with higher levels of poverty, and areas with higher pre-ACA uninsured rates.[38–40] These factors, combined with high rates of rural poverty, foster both tangible and perceived financial barriers to essential preventative health care, including HIV prevention and testing services, and drives high rates of late diagnoses in the rural South, including rural Tennessee.[26,41,42]

Additional barriers to widespread uptake of HIV testing and prevention services in the rural South include social, religious, and cultural attitudes toward HIV. HIV stigma is widespread in the South, particularly rural areas, and is often rooted in stigma around substance use disorder, minority gender identity, minority sexual orientation, and sex work.[1,26,43] Fear of stigma, social isolation, and lack of privacy result in decreased uptake of HIV testing, prevention, or treatment resources and contribute to ongoing HIV transmission and ultimately late HIV diagnoses.[44–48] Further, homophobia, transphobia, discrimination and violence targeting sexual and gender minorities, and a lack of defined LGBTQ+ communities and community organizations in many rural areas pose distinctive challenges for sexual and gender minorities in rural areas and organizations endeavoring to provide HIV-related services to these populations.[46,49,50]

Tennessee is a geographically large and diverse state and factors driving late HIV diagnoses vary between distinct rural areas. East Tennessee is part of “Appalachia”, a region with

unique social, economic, and cultural characteristics that often performs worse in many metrics compared to non-Appalachian rural counties—including poverty, unemployment, and educational attainment.[51] In addition, rural Central Appalachia, including rural East Tennessee, has been disproportionately affected by the opioid epidemic and suffers from high rates of injection drug use.[52] In East Tennessee, these factors present unique challenges for HIV testing and prevention interventions and contribute to the high rates of late HIV diagnoses observed in the region.[53] This underscores the importance of understanding not only regional and state-level factors driving late HIV diagnoses, but also unique community-level social, economic, and cultural characteristics affecting uptake of HIV-related services.

Our study demonstrated an increased risk of receiving a late HIV diagnosis among Hispanic individuals residing in majority rural counties of residence at initial HIV diagnosis compared to other racial/ethnic groups. This risk increased as county of residence became increasingly rural. These results corroborate prior studies demonstrating Hispanic individuals are more likely to be tested for HIV late, receive a late HIV diagnosis, and enter into HIV care late.[9,10,54–56] Hispanic individuals in Tennessee are more likely to be non-U.S.-born, have a first language other than English, and be non-citizens compared with other racial/ethnic groups in Tennessee. These characteristics introduce additional challenges to navigating the US health care system and accessing HIV-related services. These barriers are exacerbated by social and structural issues such as xenophobia, poverty, and mistrust of the health care system.[8,54,55,57,58] Our findings demonstrate the importance of considering cultural and linguistic factors when developing HIV testing and prevention programs.[559–62]

The results of this study demonstrate rural communities and Hispanic individuals in Tennessee are disproportionately affected by late HIV diagnoses. This highlights the importance of intensifying effective HIV-related programs and investing in the development of locally relevant interventions tailored to the needs of groups at highest risk for HIV. Tennessee recently declined ~$9 million dollars in federal funding for HIV services and announced a significant reduction in the number of partner organizations funded to provide HIV testing and prevention services to key populations.[11,53,63] The reduction in organizations funded to provide HIV testing and prevention services to key populations may have far-reaching implications for HIV in Tennessee, threatening to widen instead of narrow disparities. Despite these changes in funding, it will be essential to follow surveillance and epidemiologic data to ensure that vulnerable communities receive equitable HIV testing, prevention, and treatment services.

Limitations

This study has several limitations inherent with use of surveillance system data including survivorship bias if individuals die after HIV acquisition but prior to HIV diagnosis and selection bias if individuals residing in Tennessee were diagnosed elsewhere. Moreover, we were unable to account for unmeasured confounders, such as individual-level insurance status and income.[64,65] This study is also limited by use of 2010 decennial census data as more recent rurality data was unavailable, introducing possible measurement error. However, population trends and preliminary 2020 decennial census data suggest county population

changes between the 2010 and 2020 census are unlikely to have altered the rural-urban compositions of most Tennessee counties.[66]

There are also limitations related to the use of county of residence at the time of HIV diagnosis to define the exposure; these were captured as time-fixed and may be imperfect surrogates for contextual attributes that affect HIV prevention and care outcomes.[67] We conducted our analyses using county-specific data as TDH planning and funding for HIV-related public health initiatives are determined by county and public health region. Finally, our results may have limited generalizability outside of Tennessee, though are likely relevant for other Southern states which share similar demographic, geographic, economic, and political characteristics.

Conclusions

In Tennessee, rural residence and Hispanic ethnicity were associated with an increased risk of receiving a late HIV diagnosis. These data highlight the unique challenges and disproportionate burdens of disease that rural communities and Hispanic individuals in Tennessee face despite existing HIV testing, prevention, treatment, and linkage to care resources. Addressing disparities in HIV diagnoses begins with ensuring that vulnerable communities receive equitable HIV testing, prevention, and treatment services. To accomplish this, HIV-related programs must engage relevant community partners and focus on novel strategies designed to reach rural communities and Hispanic individuals. Ending the HIV epidemic will require collaboration between federal, state, and local public health entities, health departments, and community-based organizations to develop, implement, and deliver locally relevant HIV testing and prevention programs adapted to the needs of the communities at highest risk for HIV acquisition and adverse HIV-related health outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Centers for Disease Control & Prevention. (2019, September). HIV in the Southern United States - Centers for Disease Control and Prevention cdc.gov.https://www.cdc.gov/hiv/pdf/policies/cdc-hiv-in-the-south-issue-brief.pdf
2. McCree DH, Young SR, Henny KD, Cheever L, McCray E. U.S. Centers for Disease Control and Prevention and Health Resources and Services Administration Initiatives to Address Disparate Rates of HIV Infection in the South. AIDS Behav 2019;23(Suppl 3):313–318. doi:10.1007/s10461-019-02596-4

3. Centers for Disease Control & Prevention. (2018). HIV surveillance in urban and Nonurban areas, 2018 (preliminary) cdc.gov. https://www.cdc.gov/hiv/pdf/library/slidesets/cdc-hiv-surveillance-urban-nonurban-2018.pdf
4. Revised Surveillance Case Definition for HIV Infection — United States, 2014. Accessed December 7, 2022. https://www.cdc.gov/mmwr/preview/mmwrhtml/rr6303a1.htm?s_cid=rr6303a1_e
5. AIDSVu Tennessee. AIDSVu Accessed January 30, 2023. https://aidsvu.org/local-data/united-states/south/tennessee/
6. Centers for Diseases Control and Prevention: AtlasPlus - Maps Accessed January 30, 2023. https://gis.cdc.gov/grasp/nchhstpatlas/maps.html
7. Nduaguba SO, Ford KH, Wilson JP, Lawson KA, Cook RL. Identifying subgroups within at-risk populations that drive late HIV diagnosis in a Southern U.S. state. Int J STD AIDS 2021;32(2):162–169. doi:10.1177/0956462420947567 [PubMed: 33327899]
8. Chen NE, Gallant JE, Page KR. A systematic review of HIV/AIDS survival and delayed diagnosis among Hispanics in the United States. J Immigr Minor Health 2012;14(1):65–81. doi:10.1007/s10903-011-9497-y [PubMed: 21773882]
9. Chapin-Bardales J, Rosenberg ES, Sullivan PS. Trends in racial/ethnic disparities of new AIDS diagnoses in the United States, 1984–2013. Ann Epidemiol 2017;27(5):329–334.e2. doi:10.1016/j.annepidem.2017.04.002 [PubMed: 28506566]
10. Weis KE, Liese AD, Hussey J, Gibson JJ, Duffus WA. Associations of rural residence with timing of HIV diagnosis and stage of disease at diagnosis, South Carolina 2001–2005. J Rural Health Off J Am Rural Health Assoc Natl Rural Health Care Assoc 2010;26(2):105–112. doi:10.1111/j.1748-0361.2010.00271.x
11. “A public health crisis”: What state’s rejection of HIV funds could mean for Shelby County. The Commercial Appeal Accessed March 5, 2023. https://www.commercialappeal.com/story/news/health/2023/02/14/tennessee-hiv-funding-cdc-shelby-county-memphis-impact/69820457007/
12. Story Map Series: How Does the U.S. Census Bureau Define “Rural?” Accessed December 7, 2022. https://mtgis-portal.geo.census.gov/arcgis/apps/MapSeries/index.html?appid=49cd4bc9c8eb444ab51218c1d5001ef6
13. Local and Regional Health Departments Accessed December 7, 2022. https://www.tn.gov/health/health-program-areas/localdepartments.html
14. Bureau UC. American Community Survey (ACS) Census.gov. Accessed March 5, 2023. https://www.census.gov/programs-surveys/acs
15. Suttorp MM, Siegerink B, Jager KJ, Zoccali C, Dekker FW. Graphical presentation of confounding in directed acyclic graphs. Nephrol Dial Transplant 2015;30(9):1418–1423. doi:10.1093/ndt/gfu325 [PubMed: 25324358]
16. Azur MJ, Stuart EA, Frangakis C, Leaf PJ. Multiple imputation by chained equations: what is it and how does it work? Int J Methods Psychiatr Res 2011;20(1):40–49. doi:10.1002/mpr.329 [PubMed: 21499542]
17. Royston P, White IR. Multiple Imputation by Chained Equations (MICE): Implementation in Stata. J Stat Softw 2011;45:1–20. doi:10.18637/jss.v045.i04
18. New in Stata | Stata Accessed December 9, 2022. https://www.stata.com/new-in-stata/
19. Krueger A, Van Handel M, Dietz PM, Williams WO, Patel D, Johnson AS. HIV Testing, Access to HIV-Related Services, and Late-Stage HIV Diagnoses Across US States, 2013–2016. Am J Public Health 2019;109(11):1589–1595. doi:10.2105/AJPH.2019.305273 [PubMed: 31536400]
20. Arbona SI, Barro AS. Exploring the Spatial Determinants of Late HIV Diagnosis in Texas. Prev Chronic Dis 2020;17:E96. doi:10.5888/pcd17.190346 [PubMed: 32857031]
21. Sheehan DM, Trepka MJ, Fennie KP, et al. Individual and Neighborhood Determinants of Late HIV Diagnosis Among Latinos, Florida, 2007–2011. J Immigr Minor Health 2017;19(4):825–834. doi:10.1007/s10903-016-0422-2 [PubMed: 27119364]
22. Lyons SJ, Dailey AF, Yu C, Johnson AS. Care Outcomes Among Black or African American Persons with Diagnosed HIV in Rural, Urban, and Metropolitan Statistical Areas - 42 U.S. Jurisdictions, 2018. MMWR Morb Mortal Wkly Rep 2021;70(7):229–235. doi:10.15585/mmwr.mm7007a1 [PubMed: 33600387]

23. Ohl M, Tate J, Duggal M, et al. Rural residence is associated with delayed care entry and increased mortality among veterans with human immunodeficiency virus infection. Med Care 2010;48(12):1064–1070. doi:10.1097/MLR.0b013e3181ef60c2 [PubMed: 20966783]
24. Moring JC, Page TF, Bowen A, & Angiola J (2014). HIV Prevention and Treatment Issues in Rural America: A Focus on Regional Differences. Rural Public Health: Best Practices and Preventive Models, 169.
25. Masiano SP, Martin EG, Bono RS, et al. Suboptimal geographic accessibility to comprehensive HIV care in the US: regional and urban–rural differences. J Int AIDS Soc 2019;22(5):e25286. doi:10.1002/jia2.25286 [PubMed: 31111684]
26. Wise JM, Ott C, Azuero A, et al. Barriers to HIV Testing: Patient and Provider Perspectives in the Deep South. AIDS Behav 2019;23(4):1062–1072. doi:10.1007/s10461-018-02385-5 [PubMed: 30607759]
27. Sutton M, Anthony MN, Vila C, McLellan-Lemal E, Weidle PJ. HIV testing and HIV/AIDS treatment services in rural counties in 10 southern states: service provider perspectives. J Rural Health Off J Am Rural Health Assoc Natl Rural Health Care Assoc 2010;26(3):240–247. doi:10.1111/j.1748-0361.2010.00284.x
28. Bono RS, Dahman B, Sabik LM, et al. Human Immunodeficiency Virus-Experienced Clinician Workforce Capacity: Urban-Rural Disparities in the Southern United States. Clin Infect Dis Off Publ Infect Dis Soc Am 2021;72(9):1615–1622. doi:10.1093/cid/ciaa300
29. Galvan FH, Liu H, Brooks RA, Chen YT, Mendoza Lepe R. Using social and sexual networking mobile applications to promote HIV testing, medical care and prevention services among Latino men who have sex with men in Los Angeles County, California, USA. PloS One 2022;17(5):e0268406. doi:10.1371/journal.pone.0268406 [PubMed: 35560041]
30. Fields EL, Thornton N, Huettner S, et al. Safe Spaces 4 Sexual Health: A Status-Neutral, Mobile Van, HIV/STI Testing Intervention Using Online Outreach to Reach MSM at High Risk for HIV Acquisition or Transmission. J Acquir Immune Defic Syndr 1999 2022;90(S1):S84–S89. doi:10.1097/QAI.0000000000002968
31. Biello KB, Marrow E, Mimiaga MJ, Sullivan P, Hightow-Weidman L, Mayer KH. A Mobile-Based App (MyChoices) to Increase Uptake of HIV Testing and Pre-Exposure Prophylaxis by Young Men Who Have Sex With Men: Protocol for a Pilot Randomized Controlled Trial. JMIR Res Protoc 2019;8(1):e10694. doi:10.2196/10694 [PubMed: 30617042]
32. Biello KB, Horvitz C, Mullin S, et al. HIV self-testing and STI self-collection via mobile apps: experiences from two pilot randomized controlled trials of young men who have sex with men. mHealth 2021;7:26. doi:10.21037/mhealth-20-70 [PubMed: 33898595]
33. Horvath KJ, Lammert S, Danh T, Mitchell JW. The Feasibility, Acceptability and Preliminary Impact of Mobile Application to Increase Repeat HIV Testing Among Sexual Minority Men. AIDS Behav 2020;24(6):1835–1850. doi:10.1007/s10461-019-02755-7 [PubMed: 31823111]
34. Horvath KJ, Walker T, Mireles L, Bauermeister JA, Hightow-Weidman L, Stephenson R. A Systematic Review of Technology-Assisted HIV Testing Interventions. Curr HIV/AIDS Rep 2020;17(4):269–280. doi:10.1007/s11904-020-00506-1 [PubMed: 32507984]
35. Stephenson R, Todd K, Kahle E, et al. Project Moxie: Results of a Feasibility Study of a Telehealth Intervention to Increase HIV Testing Among Binary and Nonbinary Transgender Youth. AIDS Behav 2020;24(5):1517–1530. doi:10.1007/s10461-019-02741-z [PubMed: 31760536]
36. Osingada CP, McMorris B, Piehler TF, Tracy MF, Porta CM. Acceptability, Feasibility, and Efficacy of Telehealth Interventions for HIV Testing and Treatment in Adult Populations. Telemed J E-Health Off J Am Telemed Assoc Published online December 2, 2022. doi:10.1089/tmj.2022.0424
37. Chiou PY, Ko NY, Chien CY. Mobile HIV Testing Through Social Networking Platforms: Comparative Study. J Med Internet Res 2021;23(3):e25031. doi:10.2196/25031 [PubMed: 33769298]
38. Gai Y, Marthinsen J. Medicaid Expansion, HIV Testing, and HIV-Related Risk Behaviors in the United States, 2010–2017. Am J Public Health 2019;109(10):1404–1412. doi:10.2105/AJPH.2019.305220 [PubMed: 31415192]

39. Benitez JA, Seiber EE. US Health Care Reform and Rural America: Results From the ACA's Medicaid Expansions. J Rural Health Off J Am Rural Health Assoc Natl Rural Health Care Assoc 2018;34(2):213–222. doi:10.1111/jrh.12284
40. Menon A, Patel PK, Karmakar M, Tipirneni R. The Impact of the Affordable Care Act Medicaid Expansion on Racial/Ethnic and Sex Disparities in HIV Testing: National Findings from the Behavioral Risk Factor Surveillance System. J Gen Intern Med 2021;36(6):1605–1612. doi:10.1007/s11606-021-06590-2 [PubMed: 33501535]
41. Searing A, Adimora A. HIV and Medicaid Expansion: Failure of Southern States to Expand Medicaid Makes Elimination of HIV Infection in the United States Much Harder to Achieve. Georget Univ Health Polocy Inst- Cent Child Fam Published online November 2020:10.
42. Allen ST, O'Rourke A, White RH, et al. Barriers and Facilitators to PrEP Use Among People Who Inject Drugs in Rural Appalachia: A Qualitative Study. AIDS Behav 2020;24(6):1942–1950. doi:10.1007/s10461-019-02767-3 [PubMed: 31853771]
43. Pellowski JA. Barriers to care for rural people living with HIV: a review of domestic research and health care models. J Assoc Nurses AIDS Care JANAC 2013;24(5):422–437. doi:10.1016/j.jana.2012.08.007 [PubMed: 23352771]
44. Bond KT, Frye V, Taylor R, et al. Knowing is not enough: a qualitative report on HIV testing among heterosexual African-American men. AIDS Care 2015;27(2):182–188. doi:10.1080/09540121.2014.963009 [PubMed: 25298014]
45. Geter A, Herron AR, Sutton MY. HIV-Related Stigma by Healthcare Providers in the United States: A Systematic Review. AIDS Patient Care STDs 2018;32(10):418–424. doi:10.1089/apc.2018.0114 [PubMed: 30277814]
46. Stringer KL, Turan B, McCormick L, et al. HIV-Related Stigma Among Healthcare Providers in the Deep South. AIDS Behav 2016;20(1):115–125. doi:10.1007/s10461-015-1256-y [PubMed: 26650383]
47. Wagner AC, Hart TA, McShane KE, Margolese S, Girard TA. Health care provider attitudes and beliefs about people living with HIV: Initial validation of the Health Care Provider HIV/AIDS Stigma Scale (HPASS). AIDS Behav 2014;18(12):2397–2408. doi:10.1007/s10461-014-0834-8 [PubMed: 24965675]
48. Darlington CK, Hutson SP. Understanding HIV-Related Stigma Among Women in the Southern United States: A Literature Review. AIDS Behav 2017;21(1):12–26. doi:10.1007/s10461-016-1504-9 [PubMed: 27492025]
49. Iott BE, Loveluck J, Benton A, et al. The impact of stigma on HIV testing decisions for gay, bisexual, queer and other men who have sex with men: a qualitative study. BMC Public Health 2022;22(1):471. doi:10.1186/s12889-022-12761-5 [PubMed: 35264132]
50. Lauckner C, Lambert D, Truszczynski N, Jann JT, Hansen N. A qualitative assessment of barriers to healthcare and HIV prevention services among men who have sex with men in non-metropolitan areas of the south. AIDS Care Published online August 1, 2022:1–7. doi:10.1080/09540121.2022.2105798
51. Rural Appalachia Compared to the Rest of Rural America. Appalachian Regional Commission Accessed February 10, 2023. https://www.arc.gov/rural-appalachia/
52. Moody L, Satterwhite E, Bickel WK. Substance Use in Rural Central Appalachia: Current Status and Treatment Considerations. Rural Ment Health 2017;41(2):123–135. doi:10.1037/rmh0000064 [PubMed: 29057030]
53. HIV Surveillance Reports Accessed December 7, 2022. https://www.tn.gov/health/health-program-areas/statistics/health-data/hiv-data.html
54. Dennis AM, Napravnik S, Seña AC, Eron JJ. Late entry to HIV care among Latinos compared with non-Latinos in a southeastern US cohort. Clin Infect Dis Off Publ Infect Dis Soc Am 2011;53(5):480–487. doi:10.1093/cid/cir434
55. Torrone EA, Thomas JC, Leone PA, Hightow-Weidman LB. Late diagnosis of HIV in young men in North Carolina. Sex Transm Dis 2007;34(11):846–848. doi:10.1097/OLQ.0b013e31809505f7 [PubMed: 17595596]

56. Sheehan DM, Trepka MJ, Dillon FR. Latinos in the United States on the HIV/AIDS care continuum by birth country/region: a systematic review of the literature. Int J STD AIDS 2015;26(1):1–12. doi:10.1177/0956462414532242 [PubMed: 24810215]
57. HIV and Hispanic/Latino People in the U.S. | Fact Sheets | Newsroom | NCHHSTP | CDC Published February 6, 2023. Accessed February 13, 2023. https://www.cdc.gov/nchhstp/newsroom/fact-sheets/hiv/hispanic-latino-factsheet.html
58. Dec 20 P, 2022. Health Coverage and Care of Immigrants. KFF Published December 20, 2022. Accessed February 13, 2023. https://www.kff.org/racial-equity-and-health-policy/fact-sheet/health-coverage-and-care-of-immigrants/
59. Wyatt GE, Williams JK, Gupta A, Malebranche D. Are Cultural Values and Beliefs Included in U.S. Based HIV Interventions? Prev Med 2012;55(5):362–370. doi:10.1016/j.ypmed.2011.08.021 [PubMed: 21884721]
60. Wyatt GE. Enhancing Cultural and Contextual Intervention Strategies to Reduce HIV/AIDS Among African Americans. Am J Public Health 2009;99(11):1941–1945. doi:10.2105/AJPH.2008.152181 [PubMed: 19762666]
61. Horridge DN, Oh TS, Alonzo J, et al. Barriers to HIV Testing Within a Sample of Spanish-speaking Latinx Gay, Bisexual, and Other Men Who Have Sex with Men: Implications for HIV Prevention and Care. Health Behav Res 2019;2(3):10.4148/2572-1836.1069.
62. Mogobe KD, Shaibu S, Matshediso E, et al. Language and Culture in Health Literacy for People Living with HIV: Perspectives of Health Care Providers and Professional Care Team Members. AIDS Res Treat 2016;2016:5015707. doi:10.1155/2016/5015707 [PubMed: 27340564]
63. A A (Aima), Person Anna K, Pettit April. Where do we go from here: HIV prevention in Tennessee and beyond Published February 21, 2023. Accessed March 5, 2023. https://www.idsociety.org/science-speaks-blog/2023/where-do-we-go-from-here-hiv-prevention-in-tennessee-and-beyond/
64. Jabs AW, Jabs DA, Van Natta ML, Palella FJ, Meinert CL, Studies of the Ocular Complications of AIDS Research Group. Insurance status and mortality among patients with AIDS. HIV Med 2018;19(1):7–17. doi:10.1111/hiv.12531 [PubMed: 28696029]
65. Randall T Insurance Associated With AIDS Mortality Rates. JAMA 1993;269(22):2832. doi:10.1001/jama.1993.03500220016004 [PubMed: 8497078]
66. 2020 Population of Tennessee Counties and Incorporated Areas. Tennessee State Data Center Published August 12, 2021. Accessed February 2, 2023. https://tnsdc.utk.edu/2021/08/12/2020-population-of-tennessee-counties-and-incorporated-areas/
67. Clark CR, Williams DR. Understanding County-Level, Cause-Specific Mortality: The Great Value-and Limitations-of Small Area Data. JAMA 2016;316(22):2363–2365. doi:10.1001/jama.2016.12818 [PubMed: 27959983]

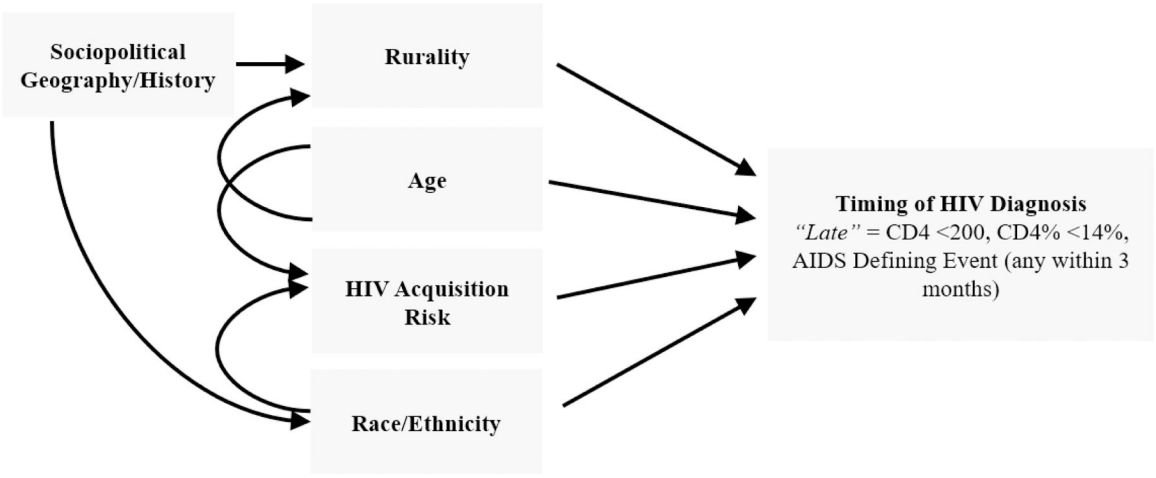

Figure 1:
Conceptual Framework for Creating a Multivariable Model

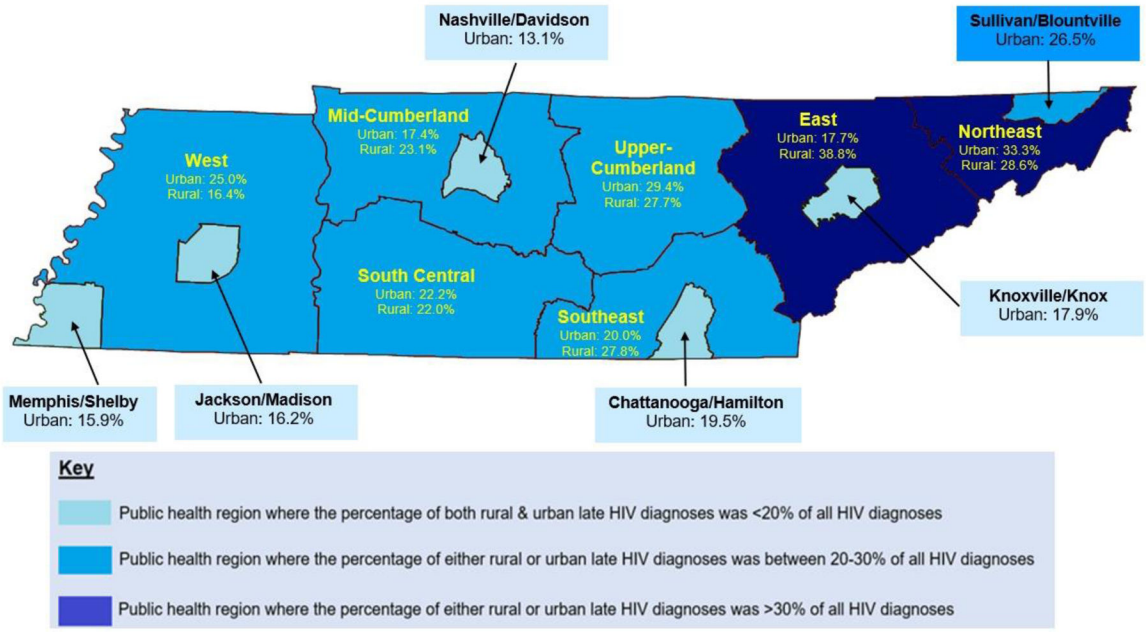

Figure 2: Proportion of HIV Diagnoses Defined as Late by Rural vs. Urban Residence & Tennessee Public Health Region (January 1, 2015- December 31, 2019)[a]

[a]This map demonstrates the geographic distribution of late HIV diagnoses by Tennessee public health regions. The percentages shown represent the percentage of HIV diagnoses that were made late in rural and urban areas within each public health region. Six regions (Madison, Shelby, Knox, Davidson, Hamilton, and Sullivan regions) are comprised entirely of urban areas; the remaining seven regions (West, South Central, Mid Cumberland, Upper Cumberland, Southeast, East, and Northeast regions) are comprised of rural and urban areas. The exclusively urban public health regions have no rural areas and thus will have no late rural HIV diagnoses.

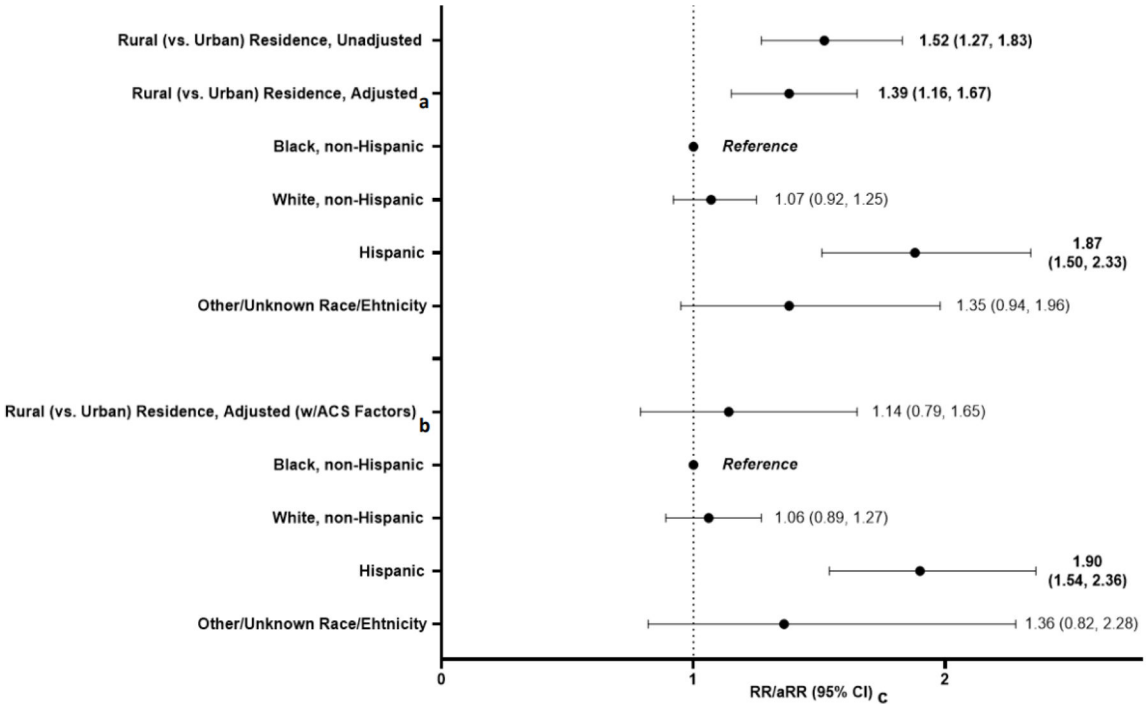

Figure 3: Primary Outcome—Risk of Late HIV Diagnosis by Rural vs. Urban Status in Tennessee

[a] Adjusted risk ratio for individual age, race/ethnicity, and year of HIV diagnosis

[b] Adjusted risk ratio for individual age, race/ethnicity, and year of HIV diagnosis and county-level educational attainment, insurance status, and poverty (obtained from American Community Survey [ACS] data).

[c] RR: Unadjusted/Crude Rate Ratio, aRR: Adjusted Rate Ratio

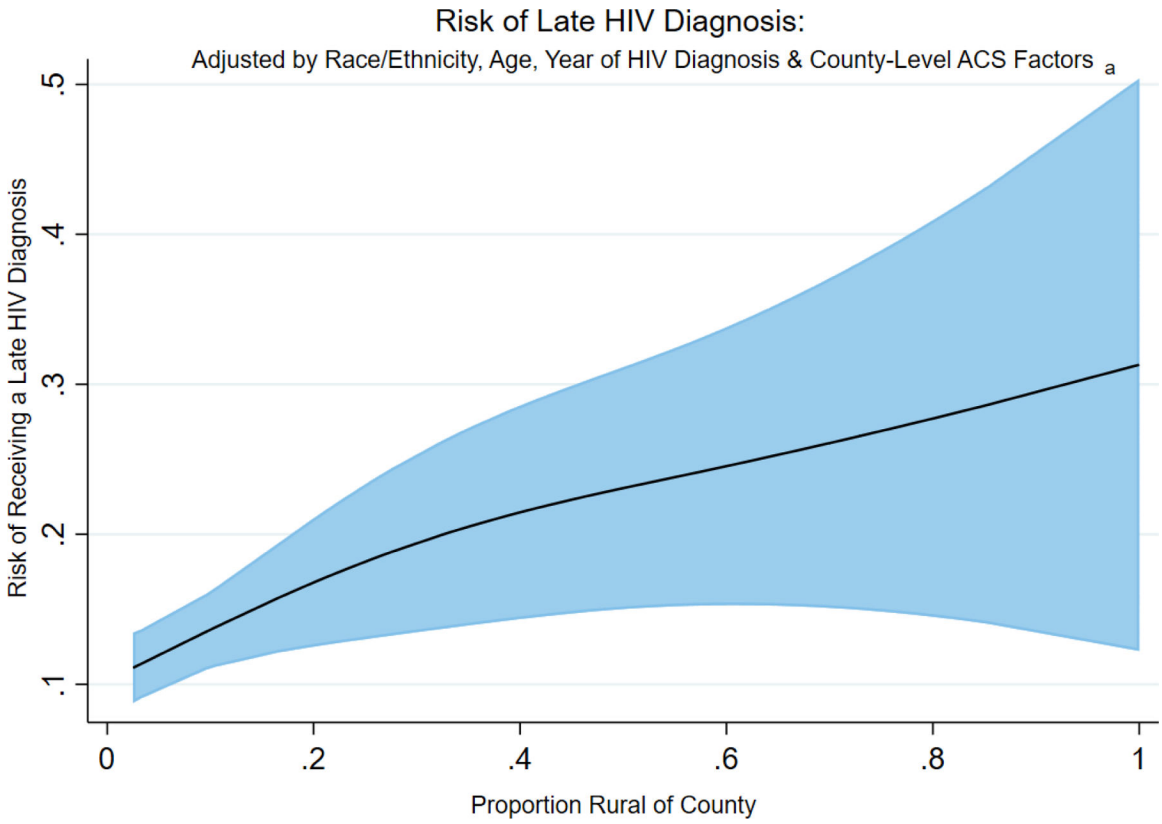

Figure 4: Risk of Late HIV Diagnosis as a Function of Rurality

[a] American Community Survey (ACS) factors in this model were obtained from the U.S. Census Bureau and include county-level educational attainment, poverty rate, and uninsured rate.

Table 1:

Baseline Characteristics of Individuals Newly Diagnosed with HIV by Urban-Rural Classification

Individuals Newly Diagnosed with HIV	**Total n=3652 (100%)**	**Urban n=3244 (88.8%)**	**Rural n=408 (11.2%)**	**Test Statistic *a***
Number of HIV Diagnoses by Year				
2015	**728** (19.9%)	**641** (19.8%)	**87** (21.3%)	p=0.104
2016	**707** (19.4%)	**611** (18.8%)	**96** (23.6%)	
2017	**709** (19.4%)	**631** (19.4%)	**78** (19.1%)	
2018	**741** (20.3%)	**668** (20.6%)	**73** (17.9%)	
2019	**767** (21.0%)	**693** (21.4%)	**74** (18.1%)	
Median Age at HIV Diagnosis	**31** (IQR: 25, 42)	**30** (IQR: 25, 42)	**33 (**IQR: 25, 46)	**p<0.001**
Gender				
Cisgender male	**2909** (79.7%)	**2582** (79.5%)	**327** (80.5%)	p=0.801
Cisgender female	**666** (18.2%)	**595** (18.3)	**71** (17.45)	
Transgender person	**77** (2.1%)	**67** (2.1%)	**10** (2.5%)	
Race/Ethnicity				
Non-Hispanic Black	**2057** (56.3%)	**1946** (60.0%)	**111** (27.2%)	**p<0.001**
Non-Hispanic White	**1241** (34.0%)	**979** (30.2%)	**262** (64.2%)	
Hispanic	**246** (6.7%)	**220** (6.8%)	**26** (6.4%)	
Other/Unknown	**108** (3.0%)	**99** (3.1%)	**9** (2.2%)	
HIV Exposure Risk Factor				
MSM	**1985** (53.8%)	**1746** (53.8%)	**239** (58.5%)	**p=0.017**
PWID	**861** (23.6%)	**757** (23.3)	**104** (25.4%)	
Heterosexual Contact	**264** (7.2%)	**241** (7.4%)	**23** (5.6%)	
Other/Unknown	**542** (14.8%)	**500** (15.4%)	**42** (10.3%)	
Tennessee Public Health Region at Time of HIV Diagnosis				
Chattanooga/Hamilton	**231**	**231** (100.0%)	**0** (0.0%)	**P<0.001**
East	**135**	**68** (50.4%)	**67** (49.6%)	
Jackson/Madison	**68**	**68** (100.0%)	**0** (0.0%)	
Knoxville/Knox	**274**	**274** (100.0%)	**0** (0.0%)	
Memphis/Shelby	**1322**	**1322** (100.0%)	**0** (0.0%)	
Mid Cumberland	**403**	**338** (83.9%)	**65** (16.1%)	
Nashville/Davidson	**724**	**724** (100.0%)	**0** (0.0%)	
Northeast	**75**	**54** (72.0%)	**21** (28.0%)	
South Central	**104**	**54** (51.9%)	**50** (48.1%)	

Individuals Newly Diagnosed with HIV	Total n=3652 (100%)	Urban n=3244 (88.8%)	Rural n=408 (11.2%)	Test Statistic *a*
Southeast	**74**	**20** (27.0%)	**54** (73.0%)	
Sullivan/Blountville	**34**	**34** (100.0%)	**0** (0%)	
Upper Cumberland	**64**	**17** (26.6%)	**47** (73.4%)	
West	**144**	**40** (27.8%)	**104** (72.2%)	
CD4 Count at HIV Diagnosis				
<200	**779** (21.3%)	**666** (20.5%)	**113** (27.7%)	**p<0.001**
>200	**2591** (71.0%)	**2325** (71.7%)	**266** (65.2%)	
Missing/Unknown	**282** (7.7%)	**253** (7.8%)	**29** (7.1%)	
Stage 3 HIV Diagnosis During Follow Up				
Yes	**849** (23.2%)	**733** (22.6%)	**116** (28.4%)	**p=0.012**
No	**2737** (76.8%)	**2511** (77.4%)	**292** (71.6%)	
Late HIV Diagnosis*b*				
Yes	**642** (17.6%)	**539** (16.6%)	**103** (25.2%)	**p<0.001**
No	**3010** (82.4%)	**2705** (83.4%)	**305** (74.8%)	

a p-values are for comparisons by Kruskal-Wallis test (continuous variables) and by Pearson $\chi 2$ (categorical variables)

b HIV diagnosis made late: defined as a stage 3 HIV diagnosis within 3 months (90 days) of initial HIV diagnosis

Abbreviations: HIV: *Human Immunodeficiency Virus*; MSM: *Men Who Have Sex with Men*; PWID: *Persons Who Inject Drugs*