Observational Study

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Role of geospatial mapping in the planning of HIV programs

A case study from Southern India

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Abstract

Geographic information systems (GIS) tools can be used to understand the spatial distribution of local HIV epidemics but are often underutilized, especially in low-middle income countries. We present characteristics of an HIV epidemic within Hyderabad, a large city in southern India, as a case study to highlight the utility of such data in program planning.

Cross-sectional sample recruited using respondent-driven sampling in a cluster-randomized trial.

We analyzed data from 2 cross-sectional respondent-driven sampling surveys of MSM in Hyderabad, which were conducted as part of a cluster-randomized trial. All participants were tested for HIV and those positive underwent viral load quantification. ArcGIS was used to create heat maps of MSM distribution using self-reported postal code of residence and combined into larger zones containing at least 200 MSM.

Postal code data was available for 661 MSM (66.2%) in the baseline and 978 MSM (97.8%) in the follow-up survey. The proportion of HIV-positive MSM (12.7–15.7%) and prevalence of virally suppressed persons (2.6–8.2%) increased between the 2 surveys. The distribution of all MSM, HIV-positive MSM, and HIV-viremic MSM differed significantly by geographic zone with several zones having higher numbers of HIV-positive and viremic individuals than would be expected based on the distribution of all MSM.

The prevalence of HIV and HIV viremia among MSM differed by geographic zones within a city and evolved over time. Such data could be critical to improving program implementation efficiency by accurately targeting resources to population characteristics.

Abbreviations: GIS = geographic information systems, IQR = interquartile range, LMICs = low-middle income countries, MSM = men who have sex with men, NACO = National AIDS Control Organization, PrEPf = pre-exposure prophylaxis, PWID = people who inject drugs, RDS = respondent-driven sampling.

Keywords: GIS, HIV/AIDS, India, key populations, MSM

Editor: Tiejun Zhang.

The study was funded by the National Institutes of Health (grants R01MH89266, DP2DA040244, K24DA035684), Johns Hopkins University Center for AIDS Research (grant P30 AI094189), and the Elton John AIDS Foundation.

The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Prabhu S, Mehta SH, McFall AM, Srikrishnan AK, Vasudevan CK, Lucas GM, Celentano DD, Solomon SS. Role of geospatial mapping in the planning of HIV programs: A case study from Southern India. Medicine 2021;100:34(e27092).

Received: 26 April 2021 / Received in final form: 5 August 2021 / Accepted: 12 August 2021

http://dx.doi.org/10.1097/MD.0000000000027092

1. Introduction

It is increasingly recognized that HIV epidemics are heterogenous within countries, states, and even within cities.[1] Consequently, examining granular spatial data can improve the efficiency of target interventions.[2,3] Geographic information systems (GIS) can be used to differentially target resources such as pre-exposure prophylaxis (PrEP) and antiretroviral therapy in cities with a focus on sub-regions (zip codes, neighborhoods, etc) with higher prevalence of persons with detectable viremia, a predictor of HIV transmission.[4,5] This can maximize the effectiveness of HIV prevention and treatment programs in a time of finite resource availability.

Use of spatial data, especially in low-middle income countries (LMICs), to guide programmatic interventions remains underutilized.[6] If geographic information is available from biobehavioral surveys and surveillance conducted among key populations such as men who have sex with men (MSM), they could help to visualize spatial distribution of HIV and viral suppression and potentially identify geographic areas of service need. These data could be crucial in developing programmatic interventions for resource allocation, identification, and intervention among high-risk populations to interrupt transmission.

This report illustrates the potential utility of geospatial data collected from a serosurvey of MSM in a high HIV prevalence city in India to tailor HIV programming.

2. Methods

Data in these analyses were collected as part of the baseline and follow-up assessments of a cluster-randomized trial among MSM in India (ClinicalTrials.gov Identifier: NCT01686750). Detailed study procedures have been published elsewhere.[7] This study was approved by the Johns Hopkins and YR Gaitonde Centre for AIDS Research and Education Institutional Review Boards. The reference number for the Johns Hopkins Institutional Review Boards is NA_00047702. With IRB approval, informed consent was obtained verbally, as this study was considered minimal risk.

Briefly, the baseline and follow-up surveys were conducted in 22 sites (10 MSM and 12 people who inject drugs (PWID)) from October 2012 to December 2013 and between August 2016 to June 2017, respectively. The study population was recruited using respondent-driven sampling (RDS), a chain-referral strategy for recruiting hard-to-reach participants.[8,9] RDS was initiated in each site using 2 "seeds" (individuals considered well-connected in the community) and allowed to run until a ~1000 participants were recruited in each site. Participants completed an interviewer-administered electronic survey and provided a blood sample. The survey captured spatial data in the form of postal code of residence for each participant. Among the demographic variables captured, sexual identity was captured and includes a diverse classification in India; *kothis* display feminine demeanor and prefer receptive anal intercourse, *panthis* display a masculine demeanor and prefer penetrative anal intercourse, and *double-deckers* engage in both receptive and penetrative intercourse.

All participants were tested for HIV on-site using three rapid tests, and all positive samples were tested for HIV RNA using the RealTime HIV-1 assay (Abbott Laboratories, Abbott Park, IL) with a lower limit of detection of 150 copies/mL. Each participant who completed the study procedures was given 2 coupons to distribute randomly to 2 other contacts (i.e., other MSM/PWID in their community). Participants were reimbursed Indian Rupees (INR) 250 (USD ~4) for completing the study visit. Further, participants could earn an incentive of INR 50 (~USD 0.80) per eligible participant referred who completed study procedures. The RDS survey, participant questionnaires, and laboratory methods were identical in the baseline and follow-up surveys.

As a case study, we utilized data among MSM from the city of Hyderabad, a city with high HIV prevalence among MSM. A shapefile containing each postal code in India was obtained and the centroid calculated. This was projected into the GCS_WGS_1984 plane using ArcGIS. Three hundred thirty-seven (33.8%) of 998 participants in the baseline survey and 22 (2.2%) of 1000 participants in the follow-up survey were dropped due to lack of postal code data. The 337 individuals who were excluded in the baseline survey did not differ from those who were included in the analyses with respect to HIV status, viral suppression, HIV viremia, age, or sexual identity.

The estimated number of MSM residing in each postal code was calculated by multiplying the weighted proportion of MSM in each postal code (calculated using RDS-2 sampling weights) by the absolute number of MSM in the city ($n = 10,172$), which was estimated using methods developed for size estimation from RDS samples based on the capture-recapture method.[10,11] Using these estimates, postal codes were collapsed into larger zones that represented at least 200 MSM.

The primary outcomes of interest were estimated numbers of MSM, numbers of HIV-positive MSM, and numbers of MSM with detectable HIV viral loads (i.e., viremic MSM) in each of the zones. The chi-squared test was used to determine whether the distribution of HIV-positive MSM was different from the distribution of all MSM; the same was also done for viremic MSM (estimated numbers of HIV-positive MSM and viremic individuals for the chi-squared test were calculated assuming that they would follow the same distribution as all MSM). ArcGIS was used to create heat maps of the distribution of MSM residences by zone. STATA version 15.1 (STATA Corp., College Station, TX) was used to generate demographic values in the tables. RDS-weighted estimates are presented in Table 1.

3. Results

The median age of the MSM in Hyderabad was 26 [interquartile range (IQR) 22–33] in the baseline survey and 27 (IQR 23–34) in the follow-up survey (Table 1). More than half (58.9% in the baseline vs. 52.6% in the follow-up) were never married in both surveys. *Panthi* was the most common sexual identity (44.3% in the baseline vs 59% in the follow-up) and *double-decker* (37.5% in the baseline vs 26.5% in the follow-up) the second most common sexual identity in both surveys. More than half the participants in both surveys had at least a secondary school education (69.8% in the baseline survey; 83.1% in the follow-up survey). Only 30.2% of the participants in the baseline survey reported a median monthly income >115 USD, while the majority (63.9%) did in the follow-up survey. The percentage of individuals who reported ever being tested for HIV (before enrolling in this study) increased from 45.3% to 50.2%.

The median lifetime number of male partners in the baseline and follow-up surveys was 14 and 6, respectively. The weighted prevalence of HIV increased from 12.7% in the baseline survey to 15.7% in the follow-up survey; however, the proportion of virally suppressed HIV-positive persons increased from 20.7% to 52%. The prevalence of MSM with detectable viremia decreased from 10% to 7.6% between the survey rounds.

Both surveys had similar geographic coverage; participants in the baseline lived in one of 80 postal codes, whereas those in the follow-up survey lived in one of 84 postal codes. Figure 1 shows the estimated number of all MSM, HIV-positive MSM and HIV-viremic MSM in each zone; both the distributions of HIV-positive MSM and HIV-viremic MSM were significantly different from the distribution of all MSM (P-value of chi-squared statistic $< .05$ for both baseline and follow-up data).

In the baseline survey, all 12 zones had more than 100 MSM and most zones had >100 HIV-positive MSM (zones v and xii were the exceptions). Similarly, in the follow-up survey, all 12 zones had more than 100 MSM, and most with >100 HIV-positive MSM (zones v, vi, and xii were the exceptions).

On the basis of the distribution of MSM in each zone, an observed versus expected ratio was calculated for both HIV-positive MSM and viremic individuals. This ratio was >1 for both HIV-positive MSM and viremic individuals in zones ii, iii, vii, and viii in the baseline survey and in zones ii, iii, v, and vii in the evaluation survey. Comparing the 2 survey periods, some areas of the city (zones ii, iii, iv, vi, vii, viii, xi) have seen a decrease in the absolute number of viremic individuals, while one (zone ix) has seen an increase between the 2 periods.

4. Discussion

This study highlights the potential utility of spatial variation of HIV disease burden among MSM in an Indian city. Although GIS

Table 1

Weighted demographics of MSM with postal code data in Hyderabad, India.

Characteristic N (column %), median (IQR)	Baseline survey (N = 661)	Follow-up survey (N = 978)
Median age	26 (22–33)	27 (23–34)
Marital status		
Never married	389 (58.9)	533 (52.6)
Currently married/ living with a partner	260 (40.1)	397 (44.8)
Divorced/widowed/ separated/other	12 (1.1)	47 (2.6)
Sexual identity		
Panthi	232 (44.3)	410 (59.0)
Kothi	177 (15.8)	220 (14.0)
Double-decker	230 (37.5)	339 (26.5)
Gay/MSM	11 (2.4)	8 (0.6)
Bisexual	1 (<0.01)	1 (<0.01)
Education		
Primary school or less	146 (20.2)	191 (16.9)
Secondary school	255 (30.0)	318 (34.8)
High school or more	260 (39.8)	469 (48.3)
Monthly income		
<$50	142 (23.8)	122 (13.9)
$50–$115	304 (46.0)	228 (22.2)
>$115	215 (30.2)	628 (63.9)
Ever tested for HIV	324 (45.3)	508 (50.2)
Median number of lifetime partners	14 (5–30)	6 (2–20)
Median number of partners with whom participant has had anal sex in prior 6 months	2 (1–4)	1 (0–2)
HIV-positive MSM	121 (12.7)	201 (15.7)
Viral suppression among HIV-positive MSM	38 (20.7)	117 (52.0)
Viral suppression	38 (2.6)	117 (8.2)
Prevalence of detectable viremia	83 (10.0)	84 (7.6)
Number of postal codes represented	80	84

has been used for years for disease surveillance and control, its potential in targeting services within urban areas has been underutilized.[12,13] The distribution of MSM, distribution of HIV-positive MSM, and viremic MSM did not perfectly correlate in the city of Hyderabad. Knowing these differences can help inform how to allocate limited resources within urban areas, especially when studying hidden populations such as MSM.[14,15]

Another benefit of studying spatial variation within a city is comparing temporal changes in the distribution of HIV-positive MSM. Although some zones of the city have seen a decrease in the number of viremic individuals over time, others have seen an interval increase. This piece of data can help identify areas where programmatic interventions are working effectively and those where interventions are needed, thereby serving as powerful tools to help programs adapt, improve efficiencies, and assist in field-based testing strategies.[16]

We present results in the forms of estimated number of absolute MSM within zones. In contrast to proportions, absolute numbers can be directly utilized by program staff for target setting and resource allocation. For instance, knowing that 20% of MSM within a zone are HIV-positive is useful, but knowing if the absolute number is 20 individuals or 200 can help allocate resources tied to programmatic targets for case detection, as well as identification of priority zones for PrEP. This information can be provided to peer-navigators/outreach workers working at the field-level to achieve prevention, testing, and treatment targets. Future directions for expanding this work include studying transmission clustering using HIV sequences, which is increasingly used in high-resource settings to identify phylogenetically linked clusters of infection.[17,18]

While we highlight the utility of such geospatial analyses, it is important to protect such data and restrict access, due to the stigma associated with behaviors such as drug use and same-sex behavior in India, especially in settings where homosexuality is still criminalized.

The spatial data presented here are self-reported and may be subject to recall bias. We used trained interviewers not from the local community and used validated questionnaires to mitigate these biases.[19–21] Although we only captured residential postal code, MSM may socialize in different areas and/or frequent multiple service locations. As there was only one study site in the city, areas that were farther away from the study site may have appeared to have a lower proportion of the population due to disproportionate recruitment closer to the study site. The baseline and follow-up datasets were not directly comparable samples; however, the purpose of this paper is to demonstrate the potential of spatial mapping in guiding programmatic interventions rather than make population-level inferences.

In conclusion, spatial mapping of key HIV outcomes could help identify areas with high transmission risk to target HIV services. The absolute number of estimates presented here, as opposed to proportions, are useful to estimate costs of service delivery, thereby directly impacting program planning and implementation. Importantly, these data help identify the needs of an at-risk and hidden population and provide a tool to target interventions at a group for which systematic data are not available.

Acknowledgment

We thank the National AIDS Control Organization (NACO), India, all our partner non-governmental organizations throughout India, our study staff, and the study participants, without whom this research would not have been possible.

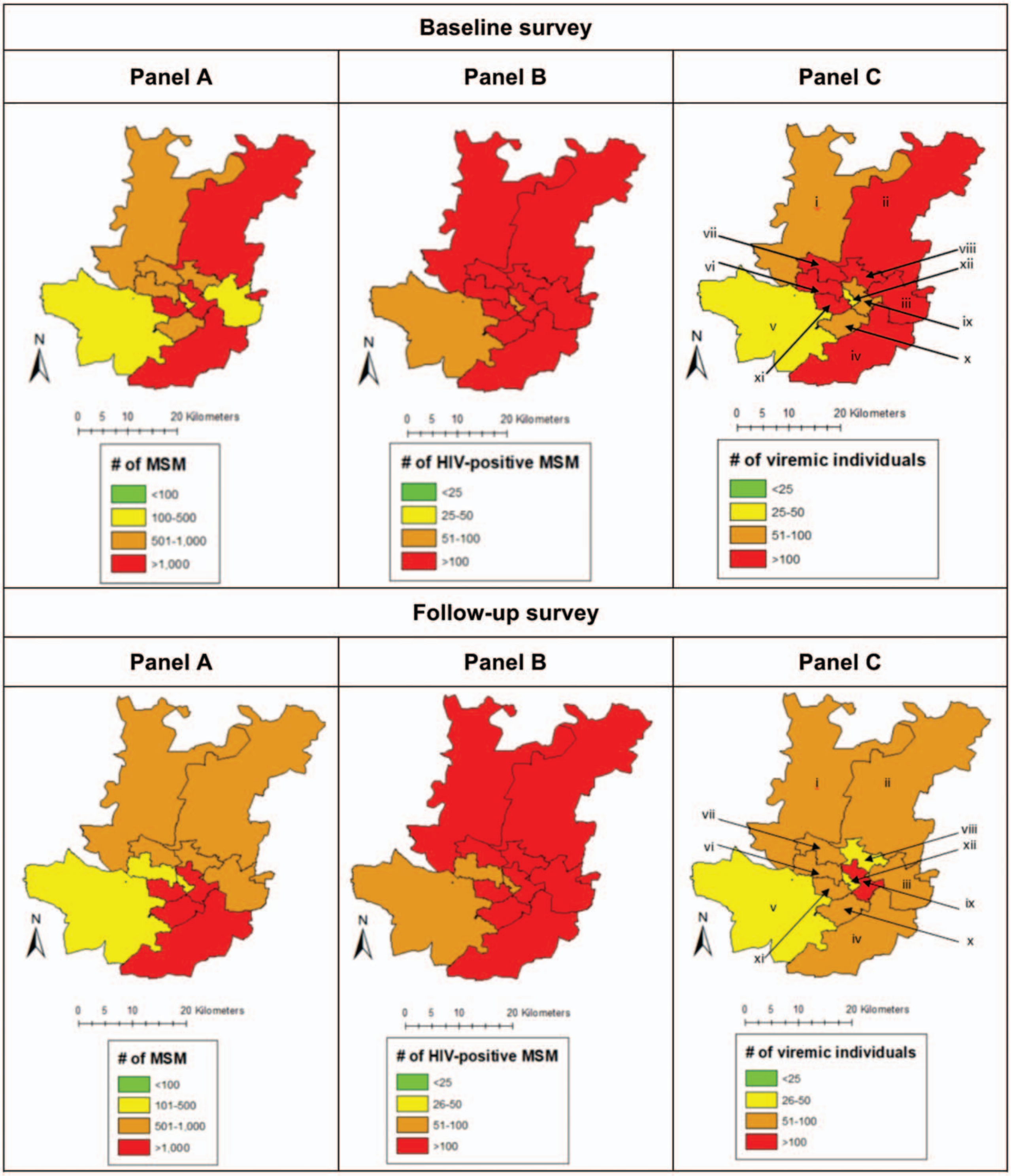

Figure 1. Spatial distribution of men who have sex with men (MSM) in Hyderabad.

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