Geospatial mapping to identify feasible HIV prevention and treatment strategies that target specific settings

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The paper recently published by Coburn, Okano, and Blower (1) proposes the use of geospatial mapping to optimize resource allocation to eliminate HIV in Lesotho, a small landlocked country in Southern Africa with a population of about 2 million and an HIV prevalence of approximately 25% in urban centers and 21% in rural settlements. In their study, the authors describe a geostatistical framework for designing a novel treatment as prevention (TasP) for HIV elimination strategy (2). They make the argument that reaching the UNAIDS goals of 90-90-90 (diagnosed-treated-virologically suppressed) may be quite difficult in some rural communities. Consequently, they propose to focus efforts in urban areas with a high density of infection.

We have previously applied geospatial clustering techniques to analyze the local HIV prevalence in Atlanta, Georgia, USA and identified that there are areas within urban areas that could be characterized as having a generalized HIV epidemic according to the World Health Organization definition at the time (2). Given the severity of the HIV epidemic in the Southern US, we used geospatial techniques to demonstrate the feasibility of reaching urban "hidden populations" who were highly susceptible to HIV in order to meet HIV prevention and treatment priorities (3). In a separate study, we used geospatial analysis to explore the impact of an emergent down-referral for 5,000 patients initially receiving HIV treatment and care in a large, urban hospital clinic in Durban, South Africa; we found that patients reduced the median distance travelled to their new, down-referral clinic by about 50% (3). In such a decentralized care model, patients save time and money on travel, thereby improving retention rates. Utilizing geospatial mapping to identify which clinics to increase resources in order to respond to the down-referral process can make such large programmatic shifts more feasible.

Thus, although geospatial mapping itself is not a novel approach to understanding HIV prevalence patterns, Coburn *et al.* obtained detailed geographic knowledge of the Lesotho epidemic and linked it to programmatic responses specifically to evaluate the feasibility and success of the 90-90-90 elimination strategy (1). In the end, the authors concluded that the UNAIDS goals for a country like Lesotho, which is geographically rural and rugged with a highly transient population, needs redirection (1). Additional commentary has offered other considerations, such as the extent of antiretroviral therapy coverage in modeling, novel strategies to surmount antiretroviral therapy (ART) delivery and access issues in rural areas, and implementation of other prevention strategies (e.g., community-based testing, partner notification) that may need to be factored into future analyses (4). Other methodological challenges with the statistical and spatial application have also been addressed including data acquisition, considerable verification and cleaning requirements, analytic time demands, and establishment of and integration of datasets for subsequent modeling (5). Nonetheless, these disadvantages may offset the importance of evaluating the feasibility of complex policy and programmatic strategies for specific countries (5).

Despite the current debate surrounding the Coburn *et al.* findings for UNAIDS policy and programming (1,4,6), and the implications for how to direct resources across Lesotho's urban and rural areas, we offer our perspective on the perspective on the utility of geospatial modeling. We argue that its value extends well beyond the scope of HIV elimination. These methodological advancements inform how best to achieve optimal responses for other health conditions in sub-Saharan Africa and beyond, including endemic diseases, non-communicable diseases, and difficult to achieve clinical care needs in complex terrain and settings (7-9).

The framework described in this study includes two main components: a country-level density of infection (DOI) map and epidemic concentration curve (ECC) plots. The DOI map is a reflection of the spatial diffusion of the epidemic in the general population of Lesotho, the size and dispersion patterns of rural and urban settlements, and geographic variation in population density (1). In the study, the geographic dispersion pattern of HIV-positive (both diagnosed and undiagnosed) individuals mirrors the spatial demographics of the population, and reflect high levels of variability within, as well as between, different healthcare districts. It is noted that although most HIV-positive individuals live in rural areas where the DOI is low, those individuals living with HIV in urban centers live in close proximity to a much greater number of uninfected individuals. For example, HIV-positive individuals live in proximity to approximately 350–500 uninfected individuals in urban areas versus 2–20 uninfected individuals in rural areas. This suggests that the risk of acquiring HIV infection is higher among the urbanized Lesotho population. The ECC, built from results of the DOI map, provides the percentage of the epidemic concentrated in urban areas and the degree of dispersion of HIV-positive individuals in rural areas. The shape of the ECC curve demonstrates that the HIV epidemic in Lesotho is predominantly rural, but that finding and treating a high percentage of HIV-positive individuals will become increasingly challenging as the treatment coverage goals increase.

Based on the resulting DOI map and ECC plots, Coburn *et al.* suggest reevaluating the current implementation of the 90-90-90 elimination strategy goals and recommend a modified TasP-based elimination strategy (1). The 90-90-90 goal is to diagnose 90% of HIV-infected individuals, treat 90% of those diagnosed, and achieve viral suppression in 90% of those being treated (10). Although the authors note that while this elimination plan may be feasible in high-income countries where HIV epidemics are concentrated among high-risk groups, achieving 90-90-90 goals in the predominantly rural and widely dispersed population of Lesotho may not be achievable, given the inaccessible areas where many of those living with HIV reside. Instead, Coburn *et al.* propose optimizing the efficiency of the TasP-based elimination strategy by allocating treatment resources based on the geographic dispersion pattern of HIV-positive individuals (i.e., allocating more treatment resources to areas with the highest DOI). Although this is currently a topic of debate, as it would result in considerable variation in coverage between districts, and likely intensify rural-urban health disparities, it would still result in the same overall reduction in the AIDS mortality rate at the national level (1,4,6).

In direct contrast to this argument is a publication by Cuadros *et al.* (11), who argue that directing prevention and treatment resources to areas with a relatively small population density, but high HIV prevalence, could in fact be more cost-effective and have greater impact compared to always allocating resources to high population density areas. The results in this study did not demonstrate a consistent association between population density and HIV prevalence; instead, the findings do suggest that in areas with a smaller population density, such as Mozambique and Tanzania, geographical variation within high burden areas was much smaller compared to the variation observed in areas with a greater population density, such as Kenya.

The stark contrast among the conclusions drawn by Coburn *et al.* (1,6), the current treatment allocation strategy implemented in Lesotho (4,10), and the findings of Cuadros *et al.* (11) underscore the importance of gathering highly sensitive local data to understand the geographic characteristics of an epidemic for the development of optimal disease elimination strategies. It is important for programs and countries (e.g., ministries of health) to consider strategies that are appropriate for their specific population and available resources.

A critical takeaway from Coburn *et al.* is not whether the current UNAIDS allocation strategy versus the study authors' proposed optimal strategy should be used one over the other. This appears to set treatment equity against treatment efficiency, a debate that is beyond the scope of this review. However, the framework developed by study authors has the potential to be used in other contexts in order to optimize resource allocation, ideally in settings in which there is no preexisting strategy. Understanding the geographic dispersion of populations with variable disease and health states is useful to developing cost-efficient and optimal treatment strategies, as it places the epidemic (or other states) in a geographic and demographic context. Coburn *et al.* suggest applying their proposed implementation design to other HIV prevention strategies, such as pre-exposure prophylaxis (PrEP) and male circumcision, and we suggest it could also be used to achieve high rates of dissemination for educational campaigns, needle exchange programs, sexually transmitted disease treatment efforts, and condom distribution.

Geospatial mapping is indispensable in that it can be easily tailored to fit the specifications of any system. As described above, geospatial mapping is not a novel approach to understanding disease distribution. However, applying data within a geographic context has wide utility for designing future cost-efficient and optimal response strategies, and even modifying current ones. For example, similar approaches to those suggested by Coburn *et al.* have been recently described to address unregulated trauma system growth (12). In order to "identify optimal resource placement," Horst *et al.* used geospatial mapping to inform the expansion of trauma center networks and suggest that strategic placement should be considered for future sites (12).

In addition to applying this framework to other HIV prevention strategies or those described by Horst *et al.*, we also suggest its applicability to other disease epidemics for which effective treatment is available, such as tuberculosis (TB). Coburn and colleagues' framework accounts for undiagnosed HIV-infected individuals (1). This suggests potential utility as an approach to latent TB case finding and treatment (13,14). Active TB case finding usually yields low cure rates and is of limited or no value to TB control, but detecting and diagnosing latent cases of TB among patients presenting at health facilities ensures treating the patient before he or she becomes symptomatic and infectious. Therefore, utilization of the framework proposed by Coburn *et al.* may prove useful in identifying key areas in which to focus available TB testing and treatment (13). Other studies have also utilized geospatial analyses to understand where the multi-drug resistant (MDR)/extensively drug-resistant tuberculosis (XDR) epidemic is within KwaZulu-Natal, South Africa, which has been critical to addressing the TB epidemic in that area (15,16). TB treatment is long-term and requires a combination of drugs. It is therefore critical that a sufficient supply of antituberculosis drugs are available so patients are able to complete treatment. The directly observed treatment strategy (DOTS) is the current TB elimination strategy recommended by the WHO (13). In addition, the strict drug regimen patients with TB require, this strategy places a large time and resource burden on healthcare providers. Beyond applications for latent TB treatment, Coburn and colleagues' framework utilizing the DOI and ECC plots may be useful in developing allocation strategies for TB drugs and the DOTS.

Eliminating HIV will require more than simply achieving the UNAIDS 90-90-90 goals. It will require that those individuals who are HIV positive and virally suppressed remain suppressed for life and that other prevention interventions are also scaled-up, such as Voluntary Medical Male Circumcision and Pre-exposure Prophylaxis. Applications of the suggested DOI and ECC plot framework could be considered for HIV treatment allocation when resources are limited, thus allowing for an effective approach for a targeted, and cost-efficient strategy. However, it has become apparent that we are unlikely to treat our way out of the epidemic and that achieving the UNAIDS 90-90-90 goals, while a significant achievement, will not eliminate HIV.

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Footnote

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References

1. Coburn BJ, Okano JT, Blower S. Using geospatial mapping to design HIV elimination strategies for sub-Saharan Africa. Sci Transl Med 2017;9. pii: eaag0019.
2. Hixson BA, Omer SB, del Rio C, et al. Spatial clustering of HIV prevalence in Atlanta, Georgia and population characteristics associated with case concentrations. J Urban Health 2011;88:129-41.
3. De Smith D, Goodchild M, P. L. Conceptual frameworks for spatial analysis. Geospatial Analysis.

5TH ed. Winchelsea (United Kingdom): Winchelsea Press; 2015. p. 51.
4. Fontaine C, Mahy M, Izazola JA, et al. Comment on "Using geospatial mapping to design HIV elimination strategies for sub-Saharan Africa". Sci Transl Med 2017;9. pii: eaan5435.
5. Spencer J. What we're reading: Geospatial analysis of HIV. In: Barton A, editor. Arlington, VA: Center for Global Health Policy; 2017.
6. Okano JT, Coburn BJ, Blower S. Response to comment on "Using geospatial mapping to design HIV elimination strategies for sub-Saharan Africa". Sci Transl Med 2017;9. pii: eaan8494.
7. Farber SH, Vissoci JR, Tran TM, et al. Geospatial analysis of unmet surgical need in Uganda: an analysis of SOSAS Survey Data. World J Surg 2017;41:353-63.
8. Shaweno D, Trauer JM, Denholm JT, et al. A novel Bayesian geospatial method for estimating tuberculosis incidence reveals many missed TB cases in Ethiopia. BMC Infect Dis 2017;17:662.
9. Madinga J, Kanobana K, Lukanu P, et al. Geospatial and age-related patterns of Taenia solium taeniasis in the rural health zone of Kimpese, Democratic Republic of Congo. Acta Trop 2017;165:100-9.
10. Joint United Nations Programme on HIV/AIDS (UNAIDS). 90-90-90 An ambitious treatment target to help end the AIDS epidemic2014.
11. Cuadros DF, Li J, Branscum AJ, et al. Mapping the spatial variability of HIV infection in Sub-Saharan Africa: Effective information for localized HIV prevention and control. Sci Rep 2017;7:9093.
12. Horst MA, Gross BW, Cook AD, et al. A novel approach to optimal placement of new trauma centers within an existing trauma system using geospatial mapping. J Trauma Acute Care Surg 2017;83:705-10.
13. Frieden TR, Munsiff SS. The DOTS strategy for controlling the global tuberculosis epidemic. Clin Chest Med 2005;26:197-205, v.
14. Rieder H. What is the role of case detection by periodic mass radiographic examination in tuberculosis control? In: Frieden T, editor. Toman's tuberculosis: case detection, treatment, and monitoring - questions and answers. Geneva (Switzerland): World Health Organization; 2004:72-9.
15. Kapwata T, Morris N, Campbell A, et al. Spatial distribution of extensively drug-resistant tuberculosis (XDR TB) patients in KwaZulu-Natal, South Africa. PLoS One 2017;12:e0181797.
16. Lim JR, Gandhi NR, Mthiyane T, et al. Incidence and Geographic Distribution of Extensively Drug-Resistant Tuberculosis in KwaZulu-Natal Province, South Africa. PLoS One 2015;10:e0132076.

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