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The Lorenz Curve: A Novel Method for Understanding Viral Load Distribution at the Population Level

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Abstract

Existing HIV care cascade metrics fail to capture whether viremia is equally distributed in a population or concentrated within groups. We applied the Lorenz cure, which has been used to describe disparities in the distribution of income and other resources, to the distribution of viremia in a safety-net HIV clinic in 2012. Among 1,855 established clinic patients, 1% of the population held 50% of the virus and 10% of the population held 94% of virus.

The HIV care cascade represents treatment success at the population level by using a cross-sectional estimate of the proportion of HIV-infected individuals who have achieved an undetectable viral load.[1] While this cascade outcome is a simple and powerful metric,[2–4] it does not capture potential heterogeneity in the distribution of viremia, that is, whether certain segments of the population hold more virus that others. Quantifying the distribution of viremia can reveal something that metrics such as “proportion suppressed” or “proportion viremic” cannot: the extent to which viremia is concentrated within a population. In addition to identifying disparities in individual health outcomes, assessing the concentration of viremia has implications for targeting HIV prevention efforts.

The Lorenz curve is a graphical representation of population distributions that has been used by economists to understand income inequality[5] and, more recently, in public health to describe the distribution of health care resources[6] and disease risks.[7] A traditional Lorenz curve plots the cumulative proportion of the population on the *x*-axis against the cumulative proportion of a resource, e.g. income, on the *y*-axis, providing a graphical representation of the distribution of the resource. If all persons hold the same amount of income, for example, then the curve is simply the straight line y=x and runs at 45 degrees from 0,0 to 1,1.. We applied the Lorenz curve to the distribution of viremia in a safety-net HIV clinic, generating a novel population-level snapshot of the status of HIV treatment in this setting.

Methods

This was a retrospective cohort study at a safety-net HIV clinic in San Francisco. Data on patient characteristics, labs, and appointments were extracted from the electronic medical record. Between January 1, 2010, and December 31, 2012, there were 3,105 patients who

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had at least one primary care visit. We excluded those not seen in 2012 (n=758), those who did not have a primary care visit at least six months prior to their first 2012 visit (n=430), those without viral load results in 2012 (n=40), and those whose most proximal viral load to 2012 was prior to 2010 (n=22), thus the study population consisted of 1,855 established clinic patients with at least one viral load measurement in 2012.

We used viremia copy-months to quantify viral exposure in our population. For example, 10,000 viremia copy-months equals having 10,000 copies of the virus every day for one month or 1,000 copies of the virus every day for 10 months. The integral of the viral load curve was approximated using the trapezoidal rule as follows: viremia copy-months were calculated between pairs of consecutive measurements in 2012 by multiplying months in the interval by the average value of the bracketing measurements.[8] For intervals spanning the start or end of 2012, the most proximal viral load measurement from 2010, 2011 or 2013 was used in a similar manner to determine the portion of viremia copy-months falling within 2012. Intervals were summed for total viremia copy-months in 2012. For patients who died in 2012 or lacked viral load measurements in 2013, viral loads were assumed to be constant until death or until the end of 2012. Analyses were performed using Stata version 13 (College Station, TX). Patients were ranked in order of their total viremia copy-months and the cumulative distribution function was calculated and graphed by plotting the cumulative portion of total viremia copy-months against the cumulative population proportion using the *glcurve* command.[9] The Committee on Human Research at the University of California San Francisco approved this study.

Results

The median age was 47 years; 13.5% were women; 46.2% were black or Latino; and about half were men who acquired HIV by having sex with men (53.3%). The median CD4 cell count was 499 cells/mm^3. Antiretroviral therapy had been prescribed to 97.3% prior to 2012 and 77.4% met a standard definition of retention in care.[10] The median time between viral load measurements was 143 days (IQR 105-196 days) and the median number of measurements per person was 2 (IQR 2-3, range 1-10) with a higher median number of measurements in those with any viral load>200 copies/mL vs. not (3 vs. 2). Applying the Lorenz curve to viremia copy-months demonstrated that 1% of the clinic population held 50% of the virus in 2012 (Figure 1). Ten percent of the clinic population held 94% of the virus. Conversely, 68% of the clinic population had a viral load <200 copies/mL at all measurements in 2012. Results using log-transformed viral loads in Lorenz curve generation were comparable (data not shown).

Discussion

Application of the Lorenz curve to evaluate the distribution of viremia in a large HIV clinic over a calendar year demonstrated a disproportionate viral load burden, with nearly all of the virus (94%) being held by 10% of the population. Given that 97% of patients had been prescribed ART and that integrase inhibitors were available, access to and effectiveness of ART do not appear to account for this clustering; lack of ART uptake, inconsistent adherence, and failure to persist with ART are more likely explanations. Caution must be

exercised in applying the Lorenz curve, in that individuals who are newly diagnosed and have high viral loads may affect estimates; we addressed this issue by focusing on patients who had been in care for at least six months. In addition, the Lorenz curve is affected by retention in clinic care. However, individuals who were ever viremic in 2012 contributed more viral load measurements than those who were never viremic. Non-suppressed patients were understandably monitored more frequently and the viremia copy-months measure used to generate the Lorenz curve utilizes all of these available time points, an important consideration given viral levels are more dynamic in non-suppressed patients.

The Lorenz curve offers a novel summary of how virus is distributed within a population and vividly illustrates the extent to which viremia can be concentrated in a small segment, a point lost by measures that dichotomize suppressed vs. non-suppressed viral loads. This analysis suggests that targeting intensive resources to a small group of patients could potentially decrease overall clinic viremia.

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E.H.G, D.V.G. and K.A.C conceived the study, K.A.C, W.H., and E.H.G. acquired and analyzed the data, K.A.C drafted the manuscript, and all authors critically revised the manuscript.

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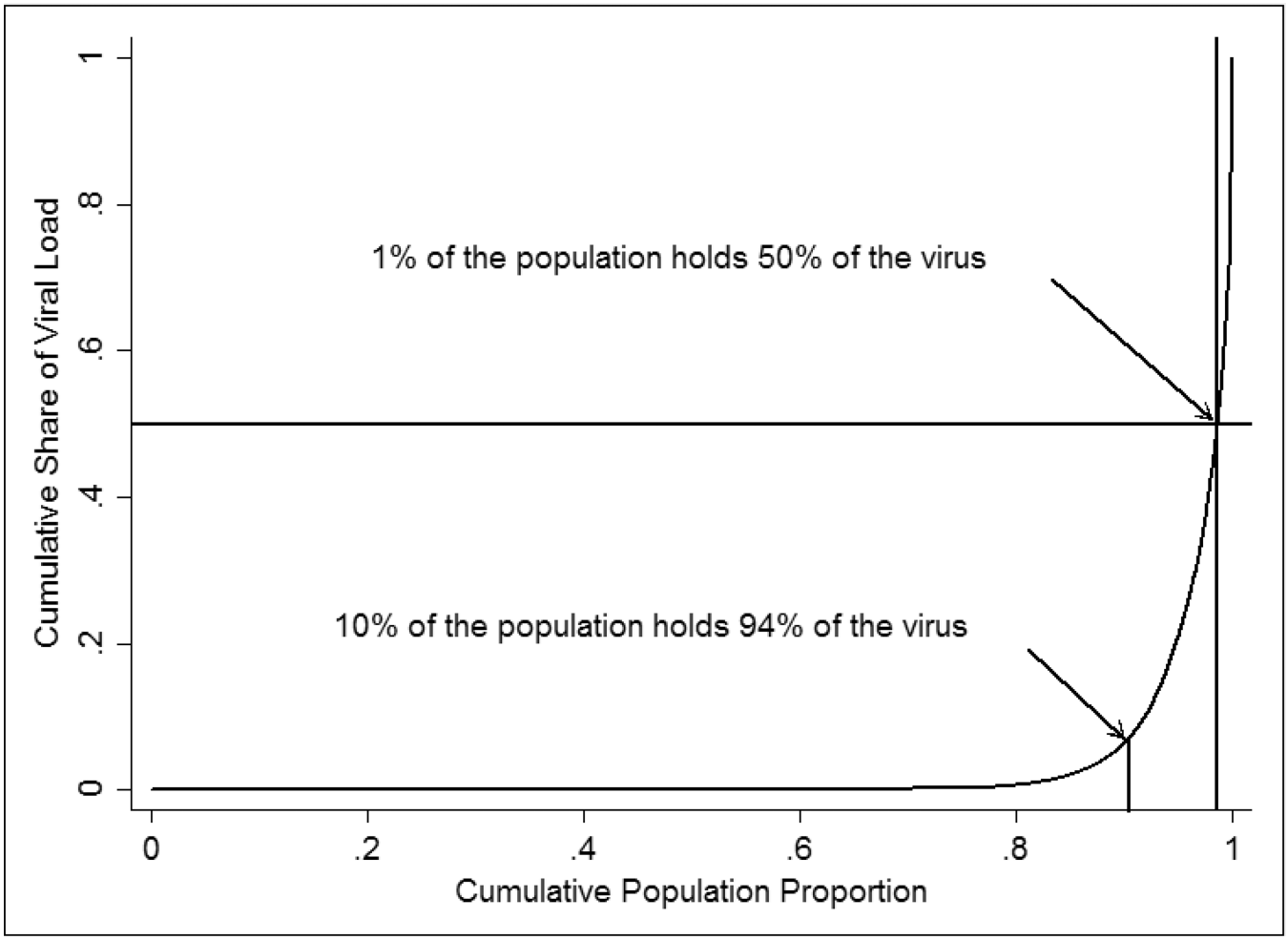

Figure 1.