Cross-sectional analysis of place-based and racial disparities in hospitalisation rates by disease category in California in 2001 and 2011

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ABSTRACT

Objectives To study the association of place-based socioeconomic factors with disease distribution by comparing hospitalisation rates in California in 2001 and 2011 by zip code median household income.

Design Serial cross-sectional study testing the association between hospitalisation rates and zip code-level median income, with subgroup analyses by zip code income and race.

Participants/setting Our study included all hospitalised adults over 18 years old living in California in 2001 and 2011 who were not pregnant or incarcerated. This included all acute-care hospitalisations in California including 1632 zip codes in 2001 and 1672 zip codes in 2011.

Primary and secondary outcomes We compared age-standardised hospitalisations per 100 000 persons, overall and for several disease categories.

Results There were 1.58 and 1.78 million hospitalisations in California in 2001 and 2011, respectively. Spatial analysis showed the highest hospitalisation rates in urban inner cities and rural areas, with more than 5000 hospitalisations per 100 000 persons. Hospitalisations per 100 000 persons were consistently highest in the lowest zip code income quintile and particularly among black patients.

Conclusion Hospitalisation rates rose from 2001 to 2011 among Californians living in low-income and middle-income zip codes. Integrating spatially defined state hospital discharge and federal zip code income data provided a granular description of disease burden. This method may help identify high-risk areas and evaluate public health interventions targeting health disparities.

INTRODUCTION

Neighbourhood-level poverty has been associated with poor health outcomes. Most studies focus on the association of neighbourhood-level poverty with specific diseases or mortality, but few explore its effect on healthcare use. Hospitalisation rates, a commonly used measure of morbidity, have been shown to be proxies for poor health, as opposed to outpatient clinic visits which may indicate appropriate treatment of preventable health conditions. Hospitalisations represent costly encounters, both high in financial expense and in morbidity. Hospital-based data are routinely collected as measures of healthcare quality, use and expenditure, and are an underused data resource in studies of the social determinants of health.

Multiple place-based factors have been identified as possible mediators of health outcomes. These include environmental exposures, the physical environment, walkability, access to healthy foods and the social environment. Low-area-level income may also impact health, with one prior experimental study showing decreased rates of obesity and diabetes in low-income individuals moving from high-poverty to low-poverty neighbourhoods. While factors that influence trends in hospitalisations include technological advances and reimbursement policies, the association of neighbourhood-level income and hospitalisations may fluctuate over time due to economic downturns and uneven implementation of public health policies that may render certain groups more vulnerable.

Understanding place-based differences in health—including healthcare use—is key to designing and implementing public health interventions. In this study, we therefore assessed population-level burden of disease based on hospitalisation rates and income in California, the most populous state in

Strengths and limitations of this study

► This is among the first statewide assessment of disease burden based on linking state hospitalisation data with federal zip code income data.
► This observational cross-sectional study is based on over 3 million hospitalisations in 2001 and 2011 combined.
► The study was limited by missing demographic data on race and gender, as much as 20% in some zip code income quintiles.
the USA. We linked state-level hospitalisation data with income data from the US Census Bureau to compare temporal and geographic differences in hospitalisation rates and zip code income in 2001 and 2011. We hypothesised that lower zip code-level income is associated with increased hospitalisation rates and that they differed between 2001 and 2011. This study provides the granularity of data needed to identify at-risk subpopulations and areas in California. It also demonstrates the use of hospital discharge data in place-based population research.

METHODS

Outcomes
In this serial cross-sectional study, our primary outcome measures were hospitalisation rates (per 100 000) for specific disease conditions. These were constructed based on data from the California Office of Statewide Health Planning and Development (OSHPD), which releases individual-level, deidentified hospital discharge data annually by county and zip code. OSHPD data include demographic information (age, race, gender), up to 25 diagnosis codes following the International Classification of Diseases (ICD) and duration of hospitalisation. Total charges accrued are also reported; they encompass all service charges during the hospitalisation, including daily hospital services and ancillary services, excluding physician charges. We compared OSHPD data for 2001 and 2011. The study was conducted with anonymised data and involved no contact with patients.

All acute care hospitalisations of persons aged 18 years or older whose residential five-digit zip codes were in California were included. Non-acute admissions to skilled nursing facilities or inpatient hospice were excluded as were hospitalisations of pregnant women and incarcerated adults. These data were tabulated by federal zip code tabulation areas, which are geographical representations of zip codes.9 For simplicity, we refer to these as zip codes throughout the manuscript. Zip code-level aggregation has been used in prior studies, with comparable heterogeneity as census tract.10 11

California adult population estimates by income category and race were obtained from the US Census Bureau. For each disease category and zip code income group, we obtained age-standardised hospitalisations by summing hospitalisations for each age group per 100 000 persons within each racial category within that age group adjusted by the percentage of California population in each age group (box 1).

Exposure
Our primary exposure variable was median household income at the zip code level, divided into quintiles. Population and zip code median household income estimates were obtained from the 2000 US Census and the 2011 5-year American Community Survey (2007–2011) from the US Census Bureau.12

Data analysis
First, we compared hospitalisation statistics for 2001 and 2011 (table 1). We included total number of hospitalisations and age-standardised hospitalisations per 100 000 person-year, mean length of stay (days) and cost of those hospitalisations per population within individual zip codes. We then reported demographic characteristics for all hospitalisations.

Next, we created income quintiles based on the distribution of annual median household income of all California zip codes from the US Census Bureau for 2000 and 2011. For 2000, the income quintiles were the following: first quintile, US$0–US$31 002; second quintile, US$31 003–US$38 697; third quintile, US$38 698–US$47 810; fourth quintile, US$47 811–US$61 766 and fifth quintile, above US$61 767. For 2011, the income quintiles were: first quintile, US$0–US$39 442; second quintile, US$39 443–US$51 644; third quintile, US$51 645–US$64 250; fourth quintile, US$64 251–US$82 633 and fifth quintile, above US$82 634. We stratified hospitalisation rates by zip code income quintile and race for both 2001 and 2011 (table 2).

Secondary analysis
In a secondary analysis, we also examined differences in hospitalisation rates by disease categories (see online supplementary file 1). The diagnostic codes for each hospitalisation were classified into the 19 disease categories used in the 2010 Global Burden of Disease Survey based on a mapping of ICD-9-CM codes (see online supplementary file 2).13–15 We mapped hospitalisation rates for the most common disease categories (see online supplementary file 3) and reported hospitalisation rates by zip code income quintile including race for all disease categories (see online supplementary files 4-6).

Missing data
Race data were missing in about 20% of hospitalisations. Sex data were missing in about 10% of hospitalisations. Observations with missing values for race or sex were omitted from rate calculations, as were the hospitalisations which were not matched to a California zip code. Out of the 1 581 543 and 1 783 145 hospitalisations in 2001 and

| Box 1 Formula for age-standardised hospitalisation rate calculation |
|---------------------------------|
| Age-standardised hospitalisation rate= (number of hospitalisations in age group 1 × %CA population in age group 1 × 100 000) / (CA population of age group 1 + (number of hospitalisations in age group 2 × %CA population in age group 2 × 100 000) / (CA population of age group 2 + (number of hospitalisations in age group 3 × %CA population in age group 3 × 100 000)) / (CA population of age group 3)) |

*When calculated for racial categories, number of hospitalisations and California population for each age group were obtained for each racial category separately. Note: age group 1 includes individuals 18–34 years old, age group 2 includes individuals 35–64 years old, and age group 3 includes individuals 65 and older. CA, California.
There was no patient or public involvement in the design or planning of the study.

### RESULTS

#### Geographical distribution of hospitalisations

Figures 2 and 3 illustrate the geographical distribution at the zip code level of median household income quintiles and hospitalisations by 100 000 persons in California, respectively. The highest zip code income quintiles in California clustered around the large metropolitan areas including the San Francisco Bay area, the Sacramento area, Los Angeles and San Diego. The bottom zip code income quintiles were found in more rural areas, as well as in isolated sections of large metropolitan areas. Between 2001 and 2011, median household income of zip codes around metropolitan areas increased, but it remained unchanged in the lower income zip codes. Higher total age-standardised hospitalisation rates (figure 3) and disease-specific hospitalisation rates (see online supplementary file 2) were found in rural and low-income zip codes.

#### Demographic characteristics and hospitalisation rates

There were 1 581 543 hospitalisations in 2001 and 1 783 145 hospitalisations in 2011 in California (table 1). Overall, there were 6339 and 6315 hospitalisations per 100 000 persons for 2001 and 2011, respectively. Between 2001 and 2011, there was no substantial difference in hospitalisations distribution by sex, whereas hospitalisations in Latinos increased by half and in individuals in the ‘other race’ category doubled (table 1).

Mean length of stay decreased and hospital charges increased from 2001 to 2011 in all zip code income quintiles. However, this masked heterogeneity by zip code-level income for expenditures. Hospital expenditure per zip code population decreased with increasing income quintiles, with the lowest zip code income quintile having US$1654 per zip code population in 2001 and US$2990 in 2011. The highest income quintile had the lowest zip code population decreased with increasing income level income for expenditures. Hospital expenditure per zip code population decreased with increasing income quintiles, with the lowest zip code income quintile having US$2561 per zip code population in 2001 and US$4473 in 2011. The highest income quintile had the lowest expenditure, with US$1654 in 2001 and US$2990 in 2011 (table 2).

There was a higher percentage of hospitalisations per zip code population over 18 years old in the lower zip code income quintiles in 2011 compared with 2001, from 7.49% of the population to 7.86% in the first (lowest) zip code income quintile and 7.23%–7.31% in the second zip code income quintile, respectively (table 2).

In comparison, hospitalisations decreased slightly in the higher income quintiles from 2001 to 2011, from 5.12% to 4.87% in the fifth (highest) income quintile (figure 3). There were more age-standardised hospitalisations in lower income zip code quintiles in 2001 compared with higher income zip codes in 2011, with higher zip code income quintiles, with 8236 and 8421 hospitalisations per 100 000 persons in the first and 5th quintile hospitalisations, respectively (table 2).
### Table 2: Demographic characteristics for all hospitalisations by zip code income, California 2001–2011

| Median household income zip code quintiles | N (%) | First quintile (lowest) | 2001 | 2011 | Second quintile (low) | 2001 | 2011 | Third quintile (middle) | 2001 | 2011 | Fourth quintile (high) | 2001 | 2011 | Fifth quintile (highest) | 2001 | 2011 |
|------------------------------------------|-------|-------------------------|------|------|------------------------|------|------|-------------------------|------|------|------------------------|------|------|------------------------|------|------|
| Population over 18                       | 6 422 577 | 3 199 202 | 4 403 545 | 5 630 115 | 5 449 073 | 6 577 564 | 5 880 284 | 6 422 577 | 5 839 227 | 5 812 685 |
| Total hospitalisations                   | 282 847 | 251 305 | 411 388 | 428 404 | 352 610 | 375 309 | 298 810 | 5 (12.7) |
| Age-standardised hospitalisations per 100 000 | 4617 | 8236 | 7401 | 6503 | 5863 | 5093 | 282 847 | 4 (8.7) |
| Mean length of stay (days)               | 5.2 | 4.9 | 5.0 | 4.7 | 4.8 | 4.7 | 4.6 | 4.6 |
| Hospital charge per population (2011 US dollars) | 2561 | 2508 | 4277 | 2150 | 3866 | 1899 | 3513 | 1654 |
| **Gender**                               |       |       |       |       |       |       |       |       |
| Male                                     | 114 920 | 114 920 | 114 920 | 114 920 | 114 920 | 114 920 | 114 920 | 114 920 |
| Female                                   | 114 920 | 114 920 | 114 920 | 114 920 | 114 920 | 114 920 | 114 920 | 114 920 |
| Unknown gender                           | 37 955 | 37 955 | 37 955 | 37 955 | 37 955 | 37 955 | 37 955 | 37 955 |
| **Race**                                 |       |       |       |       |       |       |       |       |
| White                                    | 176 914 | 176 914 | 176 914 | 176 914 | 176 914 | 176 914 | 176 914 | 176 914 |
| Black                                    | 124 052 | 124 052 | 124 052 | 124 052 | 124 052 | 124 052 | 124 052 | 124 052 |
| Latino                                   | 132 205 | 132 205 | 132 205 | 132 205 | 132 205 | 132 205 | 132 205 | 132 205 |
| Asian                                    | 16 975 | 16 975 | 16 975 | 16 975 | 16 975 | 16 975 | 16 975 | 16 975 |
| Native American                          | 142 | 142 | 142 | 142 | 142 | 142 | 142 | 142 |
| Other race                               | 4772 | 4772 | 4772 | 4772 | 4772 | 4772 | 4772 | 4772 |
| Unknown race                             | 63 535 | 63 535 | 63 535 | 63 535 | 63 535 | 63 535 | 63 535 | 63 535 |
| **Age**                                  |       |       |       |       |       |       |       |       |
| 18–34                                    | 20 059 | 20 059 | 20 059 | 20 059 | 20 059 | 20 059 | 20 059 | 20 059 |
| 35–64                                    | 99 431 | 99 431 | 99 431 | 99 431 | 99 431 | 99 431 | 99 431 | 99 431 |
| 65 and over                              | 163 357 | 163 357 | 163 357 | 163 357 | 163 357 | 163 357 | 163 357 | 163 357 |

Data from OSHPD and US Census. Age-standardised hospitalisation rates were obtained by adjusting the crude hospitalisation rate for age (using age group California coefficients) and population (using populations within each age group and zip code). Hospital charges inflation adjusted to year 2011 US dollars and divided by California population over 18 years old. Hospitalisations by demographic characteristics are crude numbers. OSHPD, Office of Statewide Health Planning and Development.
quintile. Age-standardised hospitalisation rates increased in all income quintiles except the fourth and fifth zip code income quintile (figure 4).

Age-standardised hospitalisation rates were highest in blacks for both years in all zip code income categories compared with all other racial groups (figure 5). Age-standardised hospitalisation rates decreased from 2001 to 2011 in all racial groups except for whites in the first and fifth zip code income groups, blacks in the fifth zip code income group and Latinos in the fourth and fifth zip code income groups (figure 5 and online supplementary file 1).

DISCUSSION
This study, based on over 3 million hospitalisations in 2001 and 2011 in California, highlights important disparities in healthcare use and cost according to zip code-level median household income and hospitalisation rates, which may reflect disparities in disease burden. While total age-standardised hospitalisation rates decreased from 2001 to 2011, in concordance with national hospitalisation trends, they impacted zip code income groups and racial groups differently.16 We found hospitalisation rates
Figure 4  Total hospitalisation rates by income, California. Note: data from US Census and OSHPD, GIS mapping files obtained as TIGER/Line Shapefiles from US Census (https://www.census.gov/geographies.html) and as shapefiles from Data.gov (https://www.data.gov/), both open data sites. Hospitalisations rates were obtained for each zip code income quintile by adjusting the crude hospitalisation rate for age (using age group California coefficients) and population (using populations within each age group and zip code). OSHPD, Office of Statewide Health Planning and Development.

decreased with increasing zip code income. We also noted that an overall increase in hospital expenditures masked subgroup differences, in that hospital charges were both the highest and increased the most in the lowest income quintile, highlighting a clear disparity between zip code income quintiles.

These findings are consistent with prior work, which found that young and middle-aged residents of poor US urban neighbourhoods were at higher risk of early mortality due to chronic diseases. We also noted that an overall increase in hospital expenditures masked subgroup differences, in that hospital charges were both the highest and increased the most in the lowest income quintile, highlighting a clear disparity between zip code income quintiles.

High/Q1 2001 2011

In our study, blacks made up 7% of total hospitalisations, similar to the per cent of black adults in the California population. Yet, our calculation of age-standardised hospitalisation rates per racial group exposed a disparity: blacks consistently had higher age-standardised hospitalisation rates in all zip code income groups and disease categories. Assessing overall hospitalisation rates only would have masked this disparity. California trends are similar to those at the national level, where blacks have more hospital stays than other racial groups. It has been postulated that racial disparities in the USA are driven by social disadvantages (ie, unemployment, incarceration, lower socioeconomic status), institutional racism, differential usage of healthcare services, distrust of the medical system due to past medical abuses and cumulative adverse life experiences. While neighbourhood socioeconomic status has been cited as a possible driver for increased disease burden in blacks, in our study, we see greater rates of hospitalisations in blacks regardless of zip code income as has been noted in other studies.

Some successful neighbourhood-level interventions have focused on alleviating the experience of poverty. These include community development, zoning and demolition of distressed housing. Expansion of rental vouchers programme has been supported by robust evidence of health improvements as a result of those programme. Successful neighbourhood-level interventions depend on multiple factors such as involving communities and designing multidisciplinary solutions. However, the first step to any such intervention is the identification of vulnerable populations, their geographic distribution and the presence of inequities, much like our study has done. The areas of high hospitalisation rates we identified in 2001 and 2011 still had a shortage of primary and specialty care in 2015. Our study brings
Figure 5  Total hospitalisations by race and income, California. Note: data from US Census and OSHPD, GIS mapping files obtained as TIGER/Line Shapefiles from US Census (https://www.census.gov/geographies.html) and as shapefiles from Data.gov (https://www.data.gov/), both open data sites. Hospitalisations rates were obtained for each zip code income quintile and racial group by adjusting the crude hospitalisation rate for age (using age group California coefficients) and population (using populations within each age group, racial group and zip code). OSHPD, Office of Statewide Health Planning and Development.

attention to health inequities in vulnerable populations, such as blacks, but also in vulnerable areas, notably low-income zip codes with populations with high rates of hospitalisations. Major efforts, such as the Neighborhood Atlas which maps the Area Deprivation Index, have facilitated studies on census block group-level socioeconomic deprivation and health outcomes.28 29 Future interventions could involve using such data in identifying at-risk areas that would benefit from increasing access to primary care, as studies have shown the substantial impact primary care has on mortality.30 In addition, policies could be tested to increase that access by expanding health insurance coverage.

There are several limitations to our study. One is the use of deidentified hospital discharge data instead of individual-level data, preventing calculations of incidence, prevalence or disability-adjusted life-years. Relatedly, we were not able to assess for readmissions. Also, OSHPD data do not include information on individual income or employment, and OSHPD sociodemographic data were missing for 20% of observations. Given the few demographic variables available in the OSHPD dataset, we were unable to impute missing data. Of note, it is likely that in some cases, race data were reported by hospital staff rather than patients themselves, which is likely to result in misclassification. Additionally, as we did not have access to individual addresses, we relied on zip codes; these present some limitations, since they are designed based on postal routes and may not correspond closely with neighbourhoods, and they are also larger and more heterogeneous than smaller area measures such as census tracts.31 Zip codes may represent aggregates of varying access to healthcare. Estimates may also have been biased because we had to exclude zip codes outside of California and zip codes with small numbers of residents (approximately 40%). Because we used quintiles of income aggregated at the state level, this analysis therefore does not fully capture the effects of individual zip codes; future studies could address this, while also including other zip code-level predictors like unemployment or housing that might be used to test the effects of specific local interventions. Also, certain diagnostic codes might be over-represented in hospital discharge data. As admission to a hospital usually represents a severe clinical presentation, diagnoses codes for less severe presentations may be under-represented. Additionally, although this study uses data from several years ago, it nevertheless provides insight into differences over a decade; future work should replicate this analysis with more recent data to capture the latest economic and political trends, especially after the passage and implementation of the Affordable Care Act. Finally, the standardisation method that we used would not be appropriate if we were adjusting for additional variables beyond age. Future studies could instead use different methods for multivariable adjustment.

Our study uncovers clear patterns in disparities in hospitalisation rates by zip code income at two time points 10 years apart. Future studies could extend this work to examine small area effects, which could aid the development of interventions to address these costly disparities at the zip code level. The many factors that lead to changes in hospitalisation rates—prevalence of a certain health condition, events that trigger acute presentations, access to primary care for preventable conditions—may be affected by both generalised trends, like increase in insurance coverage, and local settings, like air quality due to fires. Hospitalisation data linked to socioeconomic data offer insight on temporal and geographical trends and could also be used to estimate the effects of local, state or federal policies. Hospitalisation data can be used to measure disease burden in communities but also to assess the effect of interventions such as increasing access to primary care.

CONCLUSION

By combining spatially defined state hospitalisation data with spatially defined area-level income data, we uncovered important differences in healthcare use in...
California. The lower the zip code-level income, the greater the rates of hospitalisation. We also found that blacks have disproportionally higher rates of hospitalisation than any other racial group, regardless of zip code income. Such methods can be used by public health departments to identify ‘hot spots’ areas that would benefit from community-based interventions. By quantifying and mapping health outcomes with finer units of social demographic information, studies such as this one may help to provide guidance for allocations of limited public health resources.

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Contributors
ER conceived of the study, analysed and interpreted the data, and drafted the manuscript. RG and RH contributed to study design and data interpretation, and reviewed the manuscript critically for intellectual content. All authors read and approved of the final manuscript.

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Data from the US Census Bureau are available in a public, open-access repository. Data from OSHPD may be obtained from a third party and are not publicly available.

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