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Hepatitis C Virus Prevalence in 50 U.S. States and D.C. by Sex, Birth Cohort, and Race: 2013-2016

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Hepatitis C virus (HCV) infection is a leading cause of liver-related morbidity and mortality, and more than 2 million adults in the United States are estimated to be currently infected. Reducing HCV burden will require an understanding of demographic disparities and targeted efforts to reduce prevalence in populations with disproportionate disease rates. We modeled state-level estimates of hepatitis C prevalence among U.S. adults by sex, birth cohort, and race during 2013-2016. National Health and Nutrition Examination Survey data were used in combination with state-level HCV-related and narcotic overdose–related mortality data from the National Vital Statistics System and estimates from external literature review on populations not sampled in the National Health and Nutrition Examination Survey. Nationally, estimated hepatitis C prevalence was 1.3% among males and 0.6% among females (prevalence ratio [PR] = 2.3). Among persons born during 1945 to 1969, prevalence was 1.6% compared with 0.5% among persons born after 1969 (PR = 3.2). Among persons born during 1945 to 1969, prevalence ranged from 0.7% in North Dakota to 3.6% in Oklahoma and 6.8% in the District of Columbia. Among persons born after 1969, prevalence was more than twice as high in Kentucky, New Mexico, Oklahoma, and West Virginia compared with the national average. Hepatitis C prevalence was 1.8% among non-Hispanic black persons and 0.8% among persons of other races (PR = 2.2), and the magnitude of this disparity varied widely across jurisdictions (PR range: 1.3-7.8). Overall, 23% of prevalent HCV infections occurred among non-Hispanic black persons, whereas 12% of the population was represented by this racial group. These estimates provide information on prevalent HCV infections that jurisdictions can use for understanding and monitoring local disease patterns and racial disparities in burden of disease. (*Hepatology Communications* 2020;4:355-370).

Hepatitis C virus (HCV) infection is a leading cause of liver-related morbidity and mortality, and its sequelae cost billions of dollars in health care spending each year.(1-3) Despite being underdiagnosed and underreported, hepatitis C is the most commonly reported bloodborne infection in the United States.(1,4,5) More than 2 million adults in the United States are estimated to be currently infected.(6,7) Persons born during 1945 to 1965 have the highest prevalence of HCV infection, but new infections among young people are increasing due to injection drug use associated with opioid-use disorder.(1,6-8)

When more effective, curative direct-acting antiviral medications for hepatitis C became available in 2014, hepatitis C elimination became an imaginable goal for the first time.(9,10) States and public health coalitions have begun launching hepatitis C elimination strategies to scale up primary prevention, testing, and treatment interventions.(11-13) However, hepatitis C surveillance data for monitoring progress of such initiatives are limited.(14) HCV infection is a

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nationally notifiable disease, but chronic hepatitis C is not reportable in all states, and many acute and chronic HCV infections are undiagnosed.(1,15) The Centers for Disease Control and Prevention estimates that there are approximately 14 times more acute HCV infections than are reported as cases to national surveillance,(1) and some reports suggest this may be an underestimate.(16) Because of the under-ascertainment and lack of follow-up in traditional surveillance systems, national probability-sample sero-surveys and research studies are important sources of data for estimating hepatitis C prevalence.

Previous estimates derived from one such survey, the National Health and Nutrition Examination Survey (NHANES), have quantified the degrees to which hepatitis C prevalence is elevated among persons born during 1945 to 1965, and to which disparities exist by sex and race. Men and non-Hispanic blacks bear disproportionate burdens of infection.(17) Monitoring and understanding these disparities is helpful for targeting efforts toward reductions in hepatitis C prevalence. Given large shifts in the epidemiology of HCV infection over the previous decade, due to changing patterns of incidence, mortality and treatment, in this paper we update and extend upon previously published state-level stratified model-based prevalence estimates from NHANES for 2010.(18) We use multiple data sources for these model-based estimates of HCV RNA positivity by jurisdiction, sex, birth cohort, and race: NHANES data (1999-2016), external data sources that signal geographic patterns of HCV infection due to injection drug use, and literature-based estimates of HCV prevalence among populations not sampled by NHANES.

Methods

We used a statistical modeling approach and multiple data sources to estimate hepatitis C prevalence (HCV RNA positivity) stratified by sex, birth cohort, and race in 50 U.S. states and the District of Columbia (D.C.). This approach was previously used to estimate overall hepatitis C prevalence by state, and methods are described in detail elsewhere.(7,18) Briefly, we used U.S. NHANES data from 1999-2016 to directly estimate national hepatitis C prevalence by demographic strata. We used American Community Survey (ACS) jurisdiction-specific population distributions by these strata and National Vital Statistics System cause-of-death information to attribute prevalent cases to jurisdictions, and external literature estimates to include prevalent HCV infections from populations unsampled by NHANES (Fig. 1).

In continuous 2-year cycles, NHANES collects data on demographic characteristics and specimens for HCV RNA and antibody testing from approximately 10,000 individuals sampled to represent the U.S. noninstitutionalized, civilian population.(19,20) Using NHANES data, we directly estimated national hepatitis C prevalence in 12 strata by sex (male, female), race (non-Hispanic black, other race/ethnicities), and birth year (<1945, 1945-1969, >1969). The model could only stably support two racial/ethnic groups, and we chose to focus on the largest racial disparity—between non-Hispanic blacks versus others. However, using NHANES data, we also estimated national hepatitis C prevalence among non-Hispanic blacks, non-Hispanic whites, Hispanics, and persons of other races/ethnicities. Using the 12 strata, we

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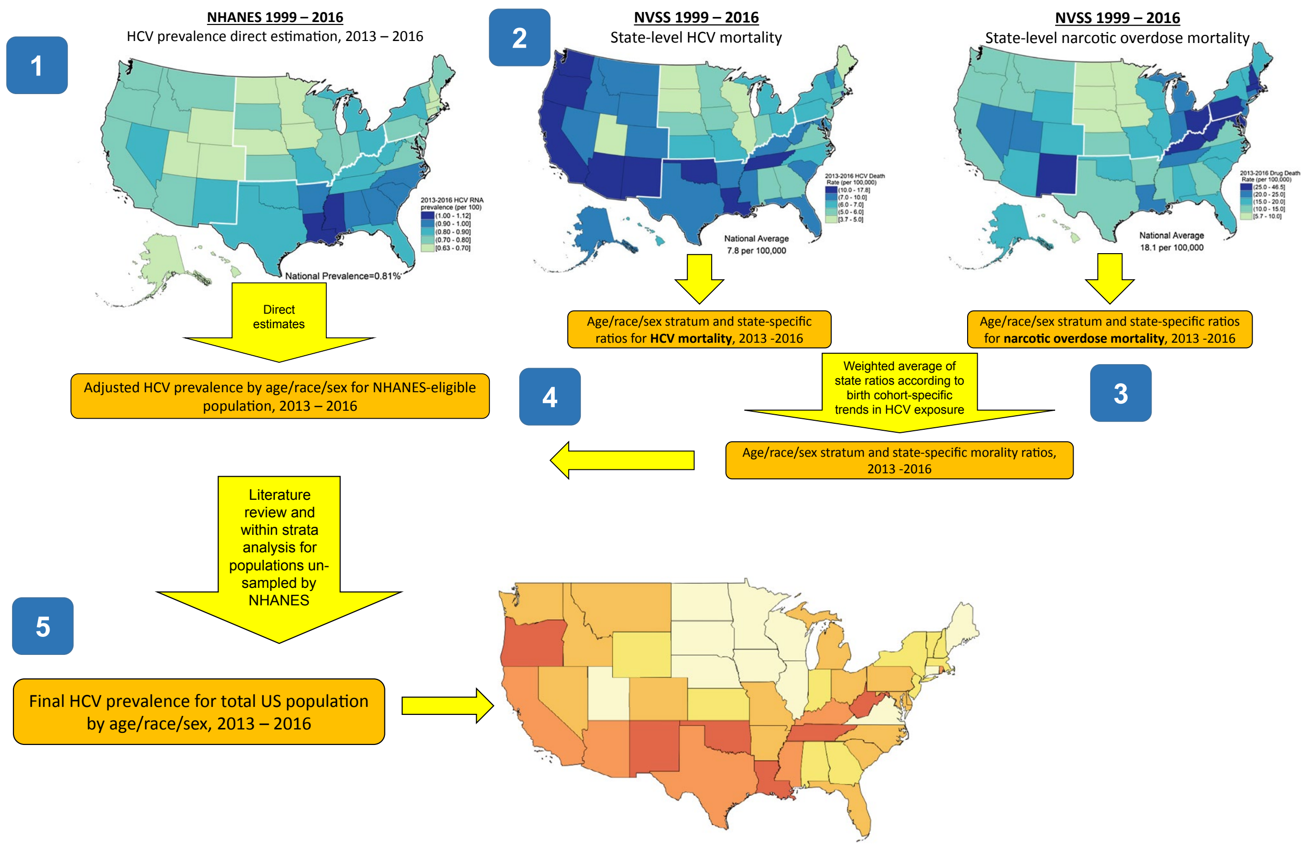

FIG. 1. Analytic steps and data sources used to estimate state-level HCV prevalence by age, race, and sex.

used logistic regression to standardize these national NHANES estimates to each jurisdiction's population distribution by sex, race, birth year, and household income (below federal poverty level [FPL], 1-1.9 times FPL, and ≥2 times FPL), as indicated by ACS data. Although persons born during 1945 to 1965 are typically grouped as a "baby boomer" birth cohort, we additionally combined persons born during 1966 to 1969 with this birth cohort, because persons born during these years were more similar to the middle versus youngest age cohort on key variables used in the present analysis. We included interaction terms for era (1999-2012, 2013-2016) to accommodate estimation for 2013-2016. The interaction terms allowed us to use all available data (1999-2016) in the model while separately outputting results for 2013-2016. The ACS 2012-2016 data were used to ascertain jurisdiction-level adult population distributions.(21,22)

Next, we used data from the National Vital Statistics System multiple-cause-of-death mortality data (1999-2016) to examine, within the demographic strata, two jurisdiction-specific mortality ratios (compared with national numbers of deaths) as signals of HCV jurisdiction-level morbidity: HCV-related mortality and narcotic overdose mortality, including overdose deaths from opioids and other drug types. Logistic regression models including jurisdiction, sex, race, birth cohort, and era were used to estimate model-based mortality counts per person years, and estimates were divided by stratum-specific national numbers of deaths to yield ratios. Within strata, these two mortality ratios were combined using weights computed from assumptions (based on directly estimated NHANES trends in HCV antibody and literature estimates) about the proportion of hepatitis C prevalence in a given birth cohort that was likely to be attributable to recent injection drug use. Finally, this weighted mortality ratio was multiplied by the previously described model-based estimates, in which directly estimated national hepatitis C prevalence from NHANES was standardized to jurisdictions within ACS-derived strata. Details regarding computation of the two cause-specific mortality rates and the weighting scheme are outlined in a previous publication.(7) We reported the model-based stratum-specific prevalences for each jurisdiction with 95% confidence intervals (Supporting Tables S1-S3). Our previously published state-level estimates were summed from the stratum-specific prevalences, as shown in these tables.(7)

INCORPORATION OF POPULATIONS NOT SAMPLED BY NHANES

Within sex, birth cohort, and race strata, we estimated jurisdiction-specific population sizes and hepatitis C prevalence for three populations not sampled by NHANES: incarcerated persons, unsheltered homeless persons, and nursing home residents. Jurisdiction-level population size estimates by strata were based on public data sources (Supporting Table S4). Hepatitis C prevalence was estimated for homeless and incarcerated populations using pooled values from a systematic literature review.(6,7) For nursing home residents, hepatitis C prevalence was estimated from NHANES data within sex and age strata and standardized to jurisdictions based on the sex and age structure of their nursing home population, according to the National Survey of Long Term Care Providers.(23)

To incorporate prevalent HCV infections in these populations to the stratified jurisdiction-specific estimates, first the hepatitis C prevalence estimate for each unsampled population as described previously was divided by the national hepatitis C prevalence directly estimated from NHANES. Prevalence ratios for each population were then multiplied by each jurisdiction's modeled hepatitis C prevalence and jurisdiction-specific population sizes for each group. The resulting estimated number of prevalent HCV infections in each population group were divided by the population group size for overall jurisdiction-specific population prevalence. For stratified estimates, the overall jurisdiction-specific population prevalence was calibrated to either hepatitis C prevalence ratios (PRs) from published studies between the strata of interest (where available) or PRs observed in the jurisdiction-specific estimates (Supporting Table S5). Finally, the number of prevalent HCV infections for each of the three populations were summed and added within strata to jurisdiction-specific estimates. Jurisdiction-level estimates were summed within strata for national estimates. All estimates were rounded to the nearest hundred.

We examined disparities by sex, birth cohort, and race. First, to examine disparities within jurisdictions and nationally, we calculated the national and jurisdiction-level PRs for males compared with females, non-Hispanic blacks compared with persons of other race/ethnicities, and persons born before 1945 and born after 1969, compared separately to persons born between 1945 and 1969. To compare jurisdictional prevalence in groups with higher than average burden of disease to the national average for that group, we calculated PRs comparing model-based jurisdiction-level prevalence within strata to the sum of model-based jurisdictional estimates (model-based national average) in the strata. Finally, to illustrate jurisdiction-level disparities within the context of local demographic distributions, we estimated the percentage of prevalent HCV infections occurring within each strata compared with the percentage of the jurisdiction's population represented by that strata. All state-level prevalence findings described here are model-based and include estimates from populations not sampled by NHANES.

Findings

SEX

Nationally, the hepatitis C prevalence estimate was 1.3% among males, ranging from 0.6% in North Dakota to 2.7% in Oklahoma (Table 1). Among females, the national hepatitis C prevalence estimate was 0.6%, ranging from 0.2% in North Dakota to 1.8% in D.C. Nationally, the PRs for males compared with females was 2.3. All jurisdictions had male:female PRs between 2.0 and 3.0 except Alaska, D.C., Wyoming (PRs < 2.0), and Maine (PRs > 3.0).

Figure 2 displays each jurisdiction by the previously estimated overall model-based hepatitis C prevalence (*x*-axis),(7) the percentage of prevalent infections occurring among females (orange section of stacked bar, 31% on average across jurisdictions), and the percentage of prevalent infections occurring among males (blue section of stacked bar, 69% on average). Each jurisdiction's proportional population distribution by sex is indicated by the black line, with the proportion of females (49% on average) represented by the area

TABLE 1. ESTIMATED PREVALENCE OF HEPATITIS C BY SEX, U.S. STATES, AND DISTRICT OF COLUMBIA, 2013-2016

	Male				Female	
State	Population	Prevalence (per 100)	PR (Ref = Female)	PR (Ref = Overall in Strata)	Population	Prevalence (per 100)
Alabama	1,782,700	1.09	2.03	0.83	1,954,000	0.54
Alaska	288,200	1.23	1.96	0.94	259,800	0.63
Arizona	2,500,000	1.78	2.45	1.36	2,590,600	0.73
Arkansas	1,094,100	1.36	2.29	1.04	1,164,600	0.59
California	14,553,900	1.55	2.37	1.18	14,990,800	0.65
Colorado	2,047,400	1.23	2.32	0.94	2,061,100	0.53
Connecticut	1,352,800	0.95	2.82	0.73	1,460,000	0.34
Delaware	348,700	1.22	2.35	0.93	381,800	0.52
District of Columbia	252,100	3.13	1.76	2.39	290,300	1.78
Florida	7,657,300	1.36	2.40	1.04	8,202,900	0.57
Georgia	3,645,200	0.99	2.18	0.76	3,952,500	0.45
Hawaii	553,300	0.84	2.92	0.64	554,100	0.29
Idaho	598,500	1.25	2.05	0.96	604,800	0.61
Illinois	4,770,100	0.74	2.24	0.56	5,072,300	0.33
Indiana	2,430,200	1.08	2.10	0.82	2,569,900	0.51
Iowa	1,169,700	0.71	2.41	0.55	1,209,600	0.30
Kansas	1,069,900	0.89	2.23	0.68	1,103,700	0.40
Kentucky	1,647,200	1.75	2.03	1.34	1,743,400	0.86
Louisiana	1,689,800	2.10	2.24	1.60	1,828,700	0.94
Maine	517,500	0.98	3.02	0.75	551,900	0.32
Maryland	2,193,100	1.25	2.31	0.95	2,409,800	0.54
Massachusetts	2,553,300	1.05	2.72	0.80	2,793,200	0.39
Michigan	3,725,200	1.24	2.14	0.95	3,951,500	0.58
Minnesota	2,049,400	0.82	2.53	0.62	2,110,500	0.32
Mississippi	1,070,900	1.42	2.13	1.08	1,180,800	0.66
Missouri	2,255,800	1.20	2.28	0.92	2,405,100	0.53
Montana	398,700	1.24	2.02	0.95	399,500	0.62
Nebraska	696,300	0.72	2.08	0.55	716,500	0.35
Nevada	1,089,100	1.43	2.41	1.09	1,088,300	0.59
New Hampshire	518,300	1.08	2.92	0.83	539,700	0.37
New Jersey	3,310,800	0.97	2.49	0.74	3,580,200	0.39
New Mexico	772,600	2.56	2.49	1.96	805,400	1.03
New York	7,376,300	1.06	2.36	0.81	8,072,200	0.45
North Carolina	3,659,600	1.22	2.26	0.93	3,980,600	0.54
North Dakota	290,900	0.60	2.71	0.46	277,400	0.22
Ohio	4,316,000	1.42	2.28	1.09	4,622,400	0.62
Oklahoma	1,430,900	2.66	2.02	2.03	1,491,800	1.31
Oregon	1,530,500	2.31	2.39	1.77	1,590,400	0.97
Pennsylvania	4,849,800	1.35	2.50	1.03	5,205,800	0.54
Rhode Island	401,900	1.78	2.65	1.36	439,400	0.67
South Carolina	1,787,400	1.35	2.28	1.03	1,952,900	0.59
South Dakota	319,600	0.73	2.23	0.56	321,400	0.33
Tennessee	2,429,100	1.96	2.13	1.50	2,624,700	0.92
Texas	9,699,200	1.44	2.24	1.10	10,078,100	0.64
Utah	1,017,400	0.78	2.07	0.60	1,024,800	0.38
Vermont	245,800	1.05	2.54	0.80	258,000	0.41
Virginia	3,124,600	0.83	2.43	0.64	3,311,800	0.34
Washington	2,711,200	1.38	2.25	1.06	2,757,700	0.61

TABLE 1. *Continued*

State	Male			PR (Ref = Overall in Strata)	Female	
	Population	Prevalence (per 100)	PR (Ref = Female)		Population	Prevalence (per 100)
West Virginia	712,800	2.01	2.18	1.54	746,600	0.92
Wisconsin	2,189,600	0.83	2.27	0.64	2,260,000	0.37
Wyoming	226,100	1.04	1.83	0.79	218,200	0.57
U.S. States and D.C.	118,920,800	1.31	2.30	-	125,761,500	0.57

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BIRTH COHORT

The highest hepatitis C prevalence by birth cohort was among persons born during 1945 to 1969, at 1.6% compared with 0.2% among persons born before 1945 and 0.5% among persons born after 1969 (Table 2). Among persons born during 1945 to 1969, prevalence ranged from 0.7% in North Dakota to 3.6% in Oklahoma and 6.8% in D.C. Prevalence ranged from 0.2% in Hawaii and in Nebraska to 1.7% in West Virginia among persons born after 1969. Nationally, the PR for persons born during 1945 to 1969 compared with those born after 1969 was 3.2, with jurisdiction-specific estimates ranging from 1.1 in West Virginia to 7.1 in Hawaii and 21.8 in D.C. The PR for persons born during 1945 to 1969 in each jurisdiction compared with the national average was 4.2 in D.C., and the PRs were also above 1.5 in Louisiana, New Mexico, Oklahoma, and Oregon. PRs for persons born after 1969 in each jurisdiction compared with the national average were above 2.0 in Kentucky, New Mexico, Oklahoma, and West Virginia.

Among all jurisdictions, 26% (range 8%-41%) of prevalent infections occurred among persons born after 1969, whereas 47% (range 39%-57%) of the population was represented by persons born after 1969 (Fig. 3). Only West Virginia had a higher percent distribution of prevalent HCV infections among persons born after 1969 versus the percent of the population represented by persons born after 1969.

RACE

Using NHANES data alone, national hepatitis C prevalence was 0.8% among Hispanics, 1.0% among non-Hispanic whites, 2.3% among non-Hispanic blacks, and 0.7% among persons of other race/ethnicities during 1999 to 2016 (Table 3). Disparities were similar in 2013-2016: 0.7% among Hispanics, 0.8% among non-Hispanic whites, 1.6% among non-Hispanic blacks, and 0.9% among persons of other race/ethnicities (data not shown).

Nationally, including populations unsampled by NHANES, hepatitis C prevalence was 1.8% among non-Hispanic blacks and 0.8% among persons of other race/ethnicities, with an overall PR of 2.2 for non-Hispanic black to persons of other race/ethnicities (Table 4). Among non-Hispanic blacks, jurisdiction-specific hepatitis C prevalence ranged from 0.9% in North Dakota to 4.5% in Montana and 4.9% in D.C. All but five jurisdictions had more than 1.0% prevalence among non-Hispanic blacks, whereas only 10 jurisdictions had more than 1.0% prevalence among persons of other race/ethnicities. The PR for non-Hispanic black to persons of other race/ethnicities ranged widely from 0.9 in Mississippi to 7.8 in Minnesota and 12.4 in D.C.

Across jurisdictions, 23% of prevalent HCV infections occurred among non-Hispanic blacks (range 1%-91%), whereas 12% (<1%-45%) of the population was represented by this racial group (Fig. 4). Only Mississippi had a lower percentage of prevalent HCV infections occurring among non-Hispanic blacks compared with the percent of the population represented by non-Hispanic blacks. Apart from D.C., jurisdictions with both a large percentage (≥30%) of prevalent infections occurring among non-Hispanic blacks and large disparities (PR ≥ 3.0) among non-Hispanic blacks compared with persons of other races were Ohio, Pennsylvania, Michigan, Maryland, New Jersey, Wisconsin, and Illinois.

Discussion

Modeled Hepatitis C prevalence estimates varied meaningfully by demographic characteristics, within

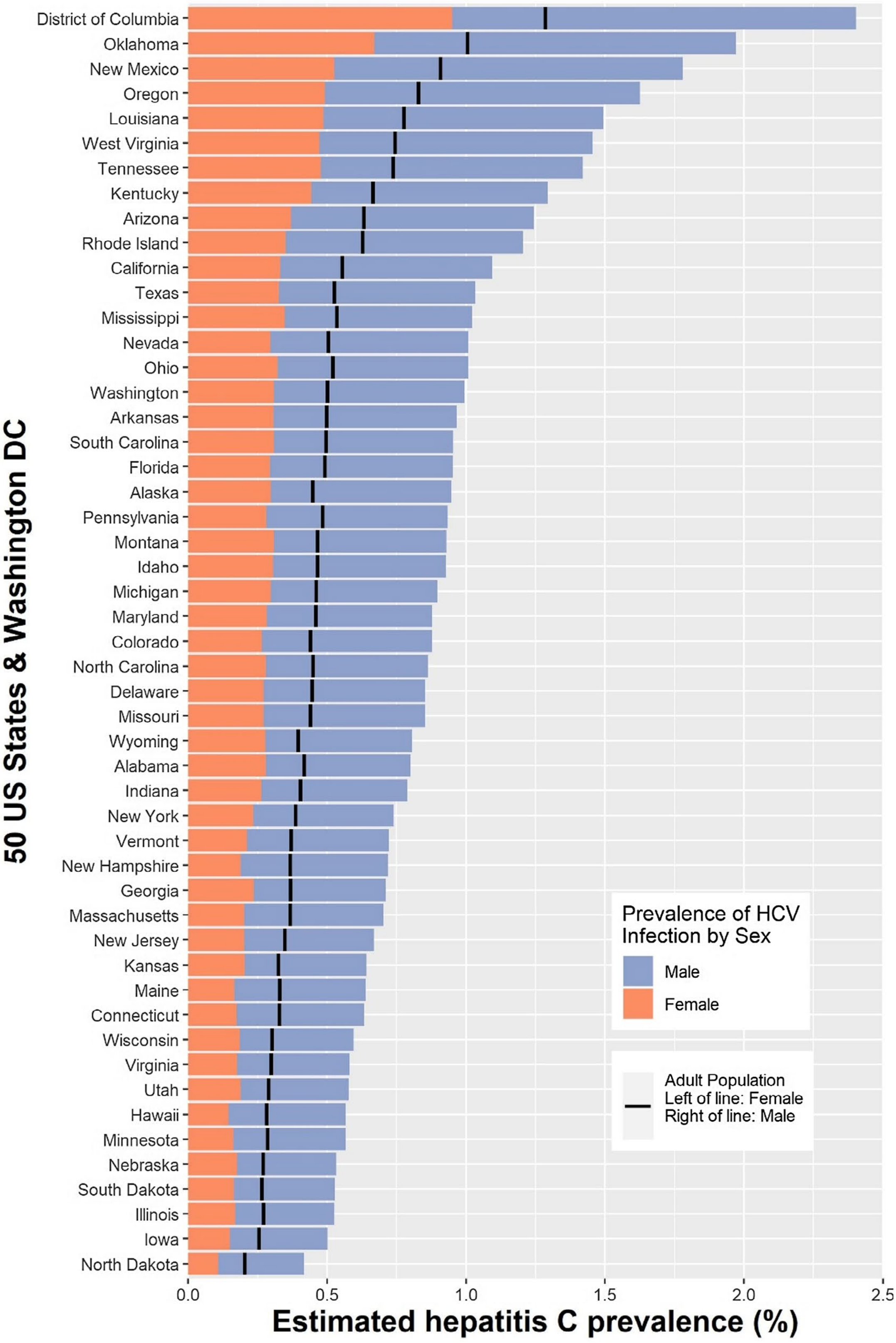

FIG. 2. Estimated hepatitis C prevalence by sex compared with state-level population distribution by sex.

TABLE 2. ESTIMATED PREVALENCE OF HEPATITIS C BY BIRTH COHORT, U.S. STATES, AND DISTRICT OF COLUMBIA, 2013-2016

	<1945			1945-1969				>1969		
State	Population	Prevalence (per 100)	PR (Ref >1969)	Population	Prevalence (per 100)	PR (Ref ≥1969)	PR (Ref = Overall in Strata)	Population	Prevalence (per 100)	PR (Ref = Overall in Strata)
Alabama	492,800	0.13	0.24	1,533,500	1.29	2.34	0.79	1,710,400	0.55	1.07
Alaska	39,500	0.22	0.51	222,000	1.73	3.93	1.06	286,400	0.44	0.86
Arizona	715,500	0.20	0.29	1,984,400	2.29	3.35	1.40	2,390,600	0.68	1.33
Arkansas	312,900	0.15	0.27	910,000	1.70	3.03	1.04	1,035,700	0.56	1.10
California	3,300,300	0.40	1.09	11,382,300	2.24	6.07	1.37	14,862,100	0.37	0.72
Colorado	428,000	0.20	0.45	1,630,600	1.60	3.61	0.98	2,050,000	0.44	0.86
Connecticut	378,800	0.11	0.24	1,209,100	0.97	2.12	0.59	1,224,900	0.46	0.89
Delaware	101,100	0.14	0.25	306,400	1.40	2.54	0.86	323,000	0.55	1.08
District of Columbia	50,900	1.06	3.36	168,000	6.84	21.75	4.19	323,500	0.31	0.61
Florida	2,627,000	0.17	0.31	6,479,000	1.68	3.05	1.03	6,754,200	0.55	1.07
Georgia	795,700	0.16	0.45	3,035,600	1.28	3.46	0.78	3,766,300	0.37	0.72
Hawaii	152,000	0.14	0.82	440,900	1.18	7.07	0.72	514,600	0.17	0.32
Idaho	150,600	0.14	0.33	478,500	1.77	4.15	1.09	574,200	0.43	0.83
Illinois	1,200,400	0.17	0.49	3,956,400	0.83	2.35	0.51	4,685,600	0.35	0.69
Indiana	626,700	0.13	0.20	2,043,400	1.17	1.88	0.72	2,330,000	0.63	1.22
Iowa	339,700	0.09	0.33	961,800	0.89	3.16	0.55	1,077,800	0.28	0.55
Kansas	281,600	0.10	0.27	863,300	1.15	3.17	0.70	1,028,600	0.36	0.71
Kentucky	427,900	0.16	0.13	1,410,100	1.77	1.51	1.09	1,552,600	1.17	2.28
Louisiana	420,400	0.40	0.47	1,406,500	2.59	3.03	1.59	1,691,700	0.85	1.67
Maine	157,900	0.08	0.13	490,600	0.84	1.38	0.51	420,900	0.61	1.18
Maryland	536,400	0.23	0.47	1,923,900	1.48	3.01	0.91	2,142,600	0.49	0.96
Massachusetts	689,700	0.11	0.20	2,194,800	1.05	1.90	0.64	2,462,100	0.55	1.08
Michigan	1,021,600	0.16	0.28	3,262,900	1.46	2.53	0.89	3,392,100	0.58	1.12
Minnesota	523,800	0.12	0.41	1,715,700	1.01	3.54	0.62	1,920,400	0.29	0.56
Mississippi	282,700	0.22	0.40	908,100	1.83	3.39	1.12	1,060,900	0.54	1.05
Missouri	626,100	0.15	0.24	1,908,100	1.36	2.24	0.83	2,126,700	0.61	1.18
Montana	110,900	0.10	0.17	343,000	1.51	2.45	0.93	344,200	0.62	1.20
Nebraska	183,800	0.12	0.56	559,800	1.03	4.64	0.63	669,200	0.22	0.43
Nevada	254,900	0.21	0.43	876,200	1.86	3.84	1.14	1,046,200	0.49	0.95
New Hampshire	135,800	0.09	0.14	480,700	0.97	1.52	0.59	441,500	0.64	1.24
New jersey	889,000	0.19	0.43	2,901,600	1.06	2.40	0.65	3,100,300	0.44	0.86
New Mexico	210,200	0.28	0.23	643,500	2.85	2.26	1.75	724,300	1.26	2.45

TABLE 2. *Continued*

	<1945			1945-1969				>1969		
State	Population	Prevalence (per 100)	PR (Ref >1969)	Population	Prevalence (per 100)	PR (Ref ≥1969)	PR (Ref = Overall in Strata)	Population	Prevalence (per 100)	PR (Ref = Overall in Strata)
New York	1,961,500	0.25	0.69	6,189,400	1.33	3.66	0.82	7,297,500	0.36	0.71
North Carolina	945,300	0.14	0.29	3,121,200	1.50	3.04	0.92	3,573,600	0.49	0.96
North Dakota	72,400	0.09	0.32	214,700	0.70	2.52	0.43	281,200	0.28	0.54
Ohio	1,209,200	0.14	0.17	3,764,300	1.46	1.73	0.89	3,964,900	0.84	1.64
Oklahoma	376,000	0.28	0.26	1,147,000	3.62	3.37	2.22	1,399,700	1.07	2.09
Oregon	411,300	0.26	0.43	1,275,600	3.23	5.45	1.98	1,433,900	0.59	1.15
Pennsylvania	1,460,200	0.14	0.19	4,229,000	1.38	1.81	0.85	4,366,400	0.76	1.48
Rhode island	114,100	0.22	0.31	346,900	2.04	2.79	1.25	380,300	0.73	1.42
South Carolina	486,400	0.16	0.34	1,554,100	1.73	3.72	1.06	1,699,800	0.47	0.91
South Dakota	86,400	0.09	0.22	258,800	0.80	1.97	0.49	295,800	0.41	0.80
Tennessee	641,800	0.22	0.23	2,082,400	2.33	2.48	1.43	2,329,600	0.94	1.83
Texas	2,019,700	0.31	0.74	7,476,800	2.07	4.94	1.27	10,280,700	0.42	0.82
Utah	196,300	0.12	0.28	680,700	0.99	2.38	0.61	1,165,200	0.41	0.81
Vermont	69,600	0.09	0.21	223,800	1.17	2.62	0.72	210,400	0.45	0.87
Virginia	751,100	0.14	0.42	2,609,700	1.01	3.11	0.62	3,075,600	0.32	0.63
Washington	641,500	0.25	0.70	2,215,700	1.95	5.41	1.20	2,611,700	0.36	0.70
West Virginia	215,400	0.10	0.06	632,400	1.73	1.05	1.06	611,500	1.65	3.22
Wisconsin	591,000	0.10	0.23	1,875,500	0.95	2.31	0.58	1,983,100	0.41	0.80
Wyoming	52,100	0.10	0.19	182,400	1.31	2.41	0.80	209,800	0.54	1.06
U.S. States and D.C.	30,765,900	0.21	0.41	98,711,100	1.63	3.18	-	115,204,300	0.51	-

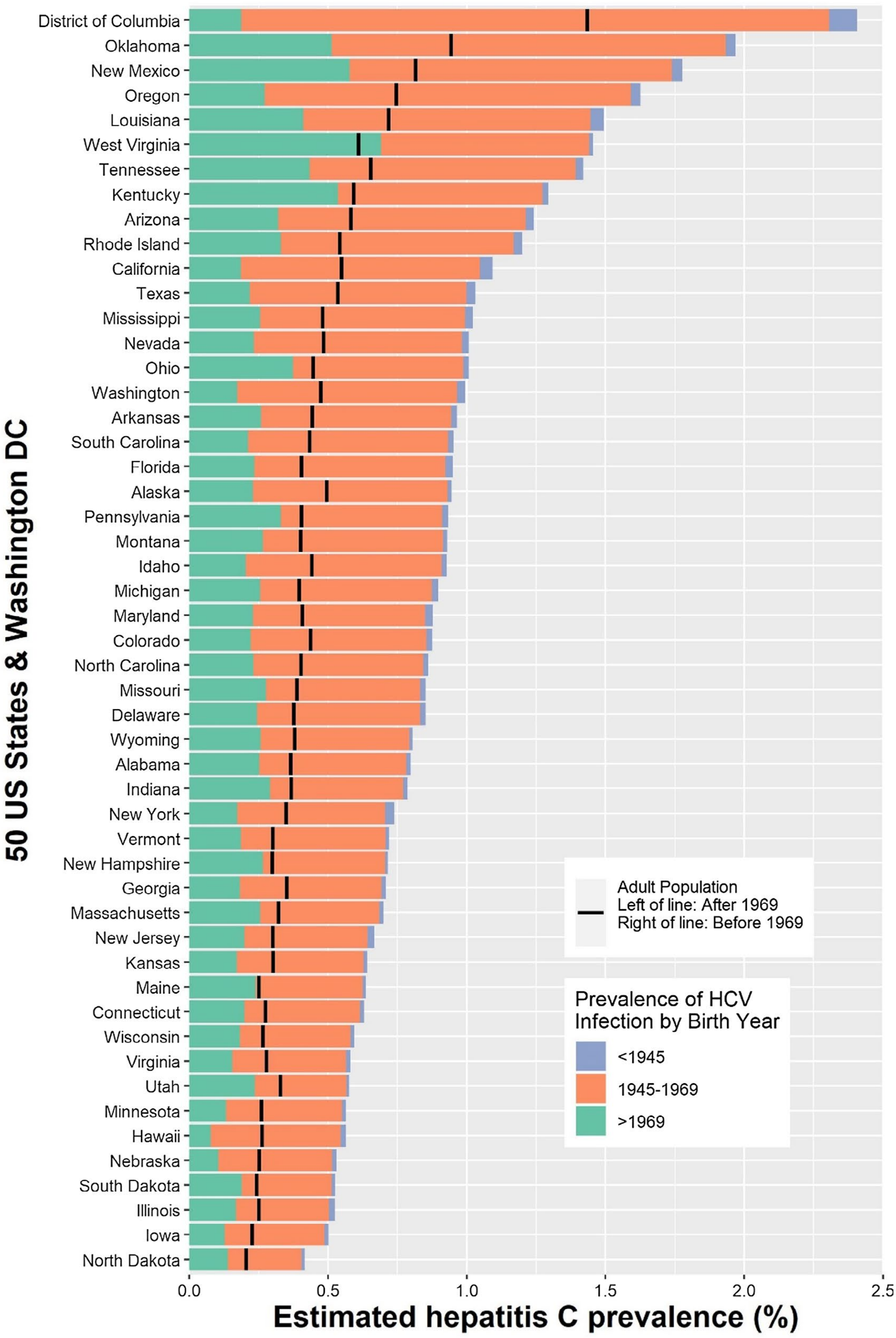

FIG. 3. Estimated hepatitis C prevalence by birth cohort compared with state-level population distribution by birth cohort.

TABLE 3. ESTIMATED PREVALENCE OF HEPATITIS C BY RACE/ETHNICITY, U.S. STATES, AND DISTRICT OF COLUMBIA, 1999-2016

	Prevalence (per 100)	95% Confidence Interval	
Hispanic	0.82	0.60	1.11
Non-Hispanic white	1.00	0.85	1.17
Non-Hispanic black	2.29	1.94	2.70
Other race/ethnicity	0.73	0.45	1.17

and across U.S. jurisdictions. In most jurisdictions, we estimated higher disease prevalence among males compared with females, persons born during 1945 to 1969 compared with older or younger persons, and non-Hispanic black persons compared with persons of other race/ethnicities. Reducing the overall number of HCV infections with a focus on disparities requires an understanding of both hepatitis C prevalence and number of infections in high-risk populations.

HCV infections are increasing among young, mostly white persons in rural areas who inject drugs,(1,24,25) but our analysis suggests that non-Hispanic blacks continue to have larger proportions of prevalent infections in most jurisdictions. Nationally, an estimated 72% of prevalent HCV infections occurred among persons born during 1945 to 1969, and even in states like West Virginia and Kentucky with higher than average percentages of infections among young people, more than 50% of all infections were still among persons born during 1945 to 1969 based on these estimates. Jurisdictions with future growth in hepatitis C burden, however, may be those with the highest prevalence of opioid-use disorder and associated injection drug use. This pattern begins to emerge to some extent in our results, in which many jurisdictions with higher than average overall prevalence are also those with larger percentages of infections among the youngest age group (e.g., New Mexico, West Virginia, Kentucky, Ohio).

We also observed that model-based hepatitis C prevalence was more than twice as prevalent among non-Hispanic black persons than among persons of other race/ethnicities, and in 15 jurisdictions, was at least 3 times as high. This disparity has been shown previously,(18) and these estimates suggest racial disparities in hepatitis C have not declined since 2010. Higher prevalence among non-Hispanic blacks compared with persons of other race/ethnicities likely stems from a combination of factors including lower rates of acute hepatitis C clearance,(26-28) higher rates of incarceration,(29-33) and less access to effective treatment services.(34-36) Clinical evidence suggested that interferon-based therapies were less effective for treating genotype 1 HCV infection among non-Hispanic black versus persons of other race/ethnicities, but newer direct-acting antiviral medications provide equally effective treatment across racial groups.(37) Efforts are urgently needed to reduce racial disparities in hepatitis C burden by increasing treatment rates among non-Hispanic black Americans through improved health coverage and development of culturally appropriate care and treatment interventions.(37,38)

Our findings suggest that lower HCV RNA prevalence estimates across nearly all jurisdictions, sex, and race groups compared with those previously modeled for 2010.(18) The two sets of estimates cannot be directly compared, because the previous estimates did not account for jurisdiction-level patterns of injection drug use or include prevalent HCV infections for populations unsampled by NHANES. Only nine jurisdictions had higher modeled prevalence in 2013-2016 than in 2010, and many of those were jurisdictions with greater numbers of infections among young people, which may have been better detected by accounting for jurisdictional patterns of injection drug use. This difference in prevalence is likely due to a combination of hepatitis C cure and HCV-related mortality since 2010, although the analysis does not allow us to estimate how much of the difference should be attributed to cure versus mortality. Rapidly evolving patterns of hepatitis C cure, mortality, and new infections associated with opioid-use disorder make hepatitis C prevalence estimation particularly important to monitor through surveillance and modeling efforts.

Although increasing access to treatment for groups with high hepatitis C burden can decrease health disparities and reduce population prevalence, parallel interventions are needed for primary hepatitis C prevention among persons who inject drugs. Incident HCV infections have increased among young people who inject drugs due to unprecedented levels of opioid-use disorder.(1,24,25,39-41) Syringe services programs and medication-assisted treatment for opioid-use disorder are both evidence-based strategies for reducing HCV transmissions in this population.(42) Mathematical models suggest that hepatitis C treatment can also reduce population prevalence among

TABLE 4. ESTIMATED PREVALENCE OF HEPATITIS C BY RACE/ETHNICITY, U.S. STATES, AND DISTRICT OF COLUMBIA, 2013-2016

	Non-Hispanic Black			PR	Other Race/Ethnicity	
State	Population	Prevalence (per 100)	PR (Ref = Non-Black)	(Ref = Overall in Strata)	Population	Prevalence (per 100)
Alabama	949,800	0.99	1.34	0.56	2,786,900	0.74
Alaska	18,200	1.34	1.43	0.75	529,800	0.94
Arizona	199,100	2.06	1.70	1.16	4,891,500	1.21
Arkansas	329,300	1.38	1.54	0.78	1,929,400	0.90
California	1,706,900	2.89	2.94	1.63	27,837,900	0.99
Colorado	153,700	2.43	2.98	1.37	3,954,800	0.82
Connecticut	263,800	1.41	2.56	0.79	2,548,900	0.55
Delaware	147,800	1.53	2.24	0.86	582,700	0.68
District of Columbia	242,900	4.91	12.44	2.76	299,500	0.39
Florida	2,265,600	1.20	1.32	0.68	13,594,600	0.91
Georgia	2,271,500	0.91	1.45	0.51	5,326,200	0.63
Hawaii	19,000	0.96	1.72	0.54	1,088,400	0.56
Idaho	6,100	1.46	1.58	0.82	1,197,200	0.93
Illinois	1,344,200	1.44	3.76	0.81	8,498,200	0.38
Indiana	426,200	1.87	2.71	1.05	4,573,800	0.69
Iowa	68,300	2.36	5.29	1.33	2,311,000	0.45
Kansas	118,200	1.71	2.94	0.96	2,055,300	0.58
Kentucky	253,400	1.97	1.59	1.11	3,137,300	1.24
Louisiana	1,065,800	2.28	1.98	1.28	2,452,700	1.15
Maine	9,900	1.47	2.33	0.83	1,059,500	0.63
Maryland	1,316,400	1.66	2.96	0.93	3,286,500	0.56
Massachusetts	333,300	1.58	2.44	0.89	5,013,300	0.65
Michigan	1,012,800	2.46	3.71	1.38	6,663,800	0.66
Minnesota	200,100	3.33	7.80	1.87	3,959,800	0.43
Mississippi	804,500	0.97	0.92	0.54	1,447,200	1.05
Missouri	508,400	1.94	2.69	1.09	4,152,400	0.72
Montana	3,100	4.49	4.89	2.53	795,000	0.92
Nebraska	59,700	2.79	6.44	1.57	1,353,100	0.43
Nevada	174,700	1.63	1.71	0.92	2,002,700	0.96
New Hampshire	11,000	1.63	2.29	0.92	1,047,000	0.71
New jersey	859,700	1.66	3.15	0.94	6,031,200	0.53
New Mexico	29,100	2.36	1.33	1.33	1,548,900	1.77
New York	2,171,000	1.60	2.68	0.90	13,277,400	0.60
North Carolina	1,582,400	1.38	1.89	0.77	6,057,700	0.73
North Dakota	10,900	0.87	2.12	0.49	557,400	0.41
Ohio	1,025,200	2.60	3.24	1.46	7,913,300	0.80
Oklahoma	204,800	2.77	1.45	1.56	2,717,900	1.92
Oregon	52,400	4.17	2.63	2.35	3,068,500	1.59
Pennsylvania	1,002,600	2.83	3.90	1.59	9,053,000	0.72
Rhode island	41,800	3.51	3.23	1.97	799,500	1.09
South Carolina	976,500	1.29	1.55	0.72	2,763,800	0.83
South Dakota	9,600	1.28	2.48	0.72	631,400	0.52
Tennessee	803,200	2.08	1.60	1.17	4,250,500	1.30
Texas	2,310,900	1.89	2.06	1.06	17,466,400	0.92
Utah	20,200	1.61	2.83	0.91	2,022,000	0.57
Vermont	4,800	2.42	3.42	1.36	499,000	0.71
Virginia	1,193,800	1.14	2.52	0.64	5,242,600	0.45

TABLE 4. *Continued*

State	Non-Hispanic Black Population	Non-Hispanic Black Prevalence (per 100)	PR (Ref = Non-Black)	PR (Ref = Overall in Strata)	Other Race/Ethnicity Population	Other Race/Ethnicity Prevalence (per 100)
Washington	188,600	2.95	3.19	1.66	5,280,400	0.93
West Virginia	45,300	3.44	2.46	1.93	1,414,000	1.40
Wisconsin	244,900	3.09	6.86	1.74	4,204,700	0.45
Wyoming	4,400	1.84	2.30	1.03	439,900	0.80
U.S. States and D.C.	29,065,800	1.78	2.19	-	215,615,900	0.81

groups at highest HCV infection risk and prevent new transmissions.(2,39) In addition to development of effective interventions for delivery of these services, comprehensive care is needed for persons who inject drugs to sustain hepatitis C prevention programs.(24,39,43)

One important limitation of our analysis is the inability to produce separate state-level hepatitis C prevalence estimates for Hispanics. Due to data sparsity in population-level positive HCV RNA results by race/ethnicity, our model could stably produce state-level results for two racial categories. Using the national NHANES data, we found slightly lower hepatitis C prevalence among Hispanics compared with non-Hispanic whites. Previous research comparing HCV antibody by race/ethnicity corroborates this finding, with similar or slightly lower antibody prevalence estimated among Hispanics compared with non-Hispanic whites.(18,44) Despite similar HCV prevalence, however, Hispanics have worse HCV-related morbidity and mortality outcomes than non-Hispanic whites, including liver cancer(45-47) and mortality attributable to hepatitis C.(48) Liver disease is the seventh-leading cause of disease among Hispanics in the United States.(49) Because this analysis aimed to describe disparities in HCV prevalence rather than outcomes, we focused on the historically(18,50,51) and currently larger disparity between blacks and persons of other race/ethnicities. Elucidation of state-level HCV prevalence and related outcomes among Hispanic populations is an important area for future research and modeling.

Our modeling approach has other limitations.(7) The use of mortality-based signals for jurisdiction-level HCV RNA infection prevalence may not capture all geo-spatial variation in HCV-related mortality and deaths attributable to injection drug use. Narcotic overdose deaths are an imperfect signal for injection drug use because of geographic variation in both types of narcotics used, how likely they are to be injected, and laws and interventions intended to reduce overdose deaths. Moreover, if underreporting of HCV-related mortality is differential by jurisdiction, this may compromise the reliability of these mortality estimates as a geographic signal for underlying hepatitis C prevalence. Population size and hepatitis C morbidity estimates for populations not sampled by NHANES were data-informed but may not fully capture the number of HCV infections in those populations. Hepatitis C prevalence data by demographic strata are particularly limited for populations unsampled by NHANES, so assumptions based on available data had to be made for stratified estimation in these groups (Supporting Table S4). Published estimates of hepatitis C morbidity in the incarcerated population may be higher or lower than underlying prevalence, which would be better captured with routine screening. Because of the estimation methods used for unsampled populations, we were unable to compute standard errors and accompanying confidence intervals around prevalence estimates. Stratum-specific numbers of HCV infections in NHANES serve as the basis for modeled estimates and are more limited in groups with lower NHANES-based prevalence. Finally, these estimates represent prevalent rather than incident infections. Prevalent infections comprise both older and new infections, so disparities observed in these data reflect both historical disease patterns and the changing epidemiology of HCV infection. Despite these limitations, this method uses a powerful national database with biomarkers for prevalent HCV infection, well-established geo-spatial markers of hepatitis C morbidity, nearly exact standardization to jurisdictional populations, and thorough research on populations unsampled by NHANES to produce hepatitis C prevalence estimates.

These model-based estimates provide updated and comprehensive information on prevalent HCV infections that jurisdictions can use for understanding

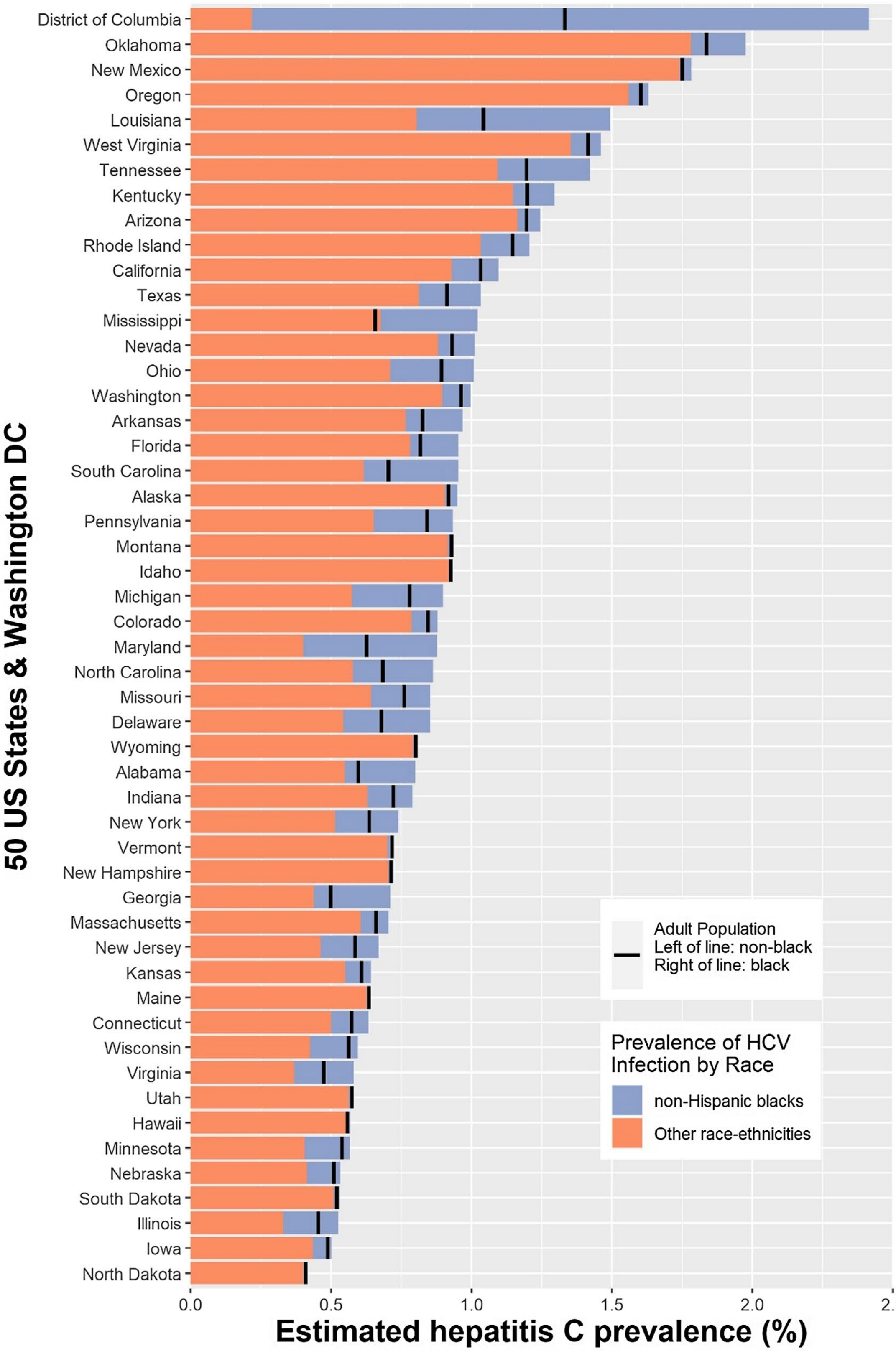

FIG. 4. Estimated hepatitis C prevalence by race compared with state-level population distribution by race.

local disease patterns and allocating resources accordingly. Strengthened state-level hepatitis surveillance is needed for optimal monitoring of HCV disease patterns as incident infections rise among persons who inject drugs and curative therapies become increasingly accessible. However, progress toward HCV elimination and reductions in observed disparities cannot wait for surveillance systems to mature. Modeled estimates can guide policy and programs for preventing and treating HCV infection by elucidating populations with the greatest need for intervention.

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Supporting Information

Additional Supporting Information may be found at onlinelibrary.wiley.com/doi/10.1002/hep4.1457/suppinfo.