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Factors associated with utilization of mobile health clinic hepatitis C virus services among medically underserved communities in South Carolina

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Abstract

Background Mobile health clinics (MHCs) are effective mechanisms for hepatitis C virus (HCV) screening and treatment in underserved populations. However, effective strategies for identifying and prioritizing high-risk communities are lacking. This study examined individual-level and community-level predictors of MHC utilization, HCV positivity rates, and HCV treatment initiation to assess the utility of these programs and improve MHC allocation.

Method Clemson Rural Health (CRH), a health service delivery organization focused on rural and underserved communities, mobilizes MHCs for HCV screening and treatment initiation in the Upstate and Midlands regions of South Carolina. Participants for this study were individuals screened at CRH MHC sites between May 2021 and January 2024. Generalized linear mixed-effects models were used to examine the association between community-level predictors and number of individuals screened and community- and individual-level predictors and infection status and treatment initiation.

Results The community-level analysis showed that individuals from census tracts with higher rates of poverty (relative risk; $RR = 1.32$, $p = .012$), higher rates of uninsurance ($RR = 1.31$, $p = .003$), and less rural areas ($RR = 0.74$, $p = .029$) were more likely to utilize the MHC for HCV screening. The individual-level analysis showed that an individual's age of 30–44 ($RR = 2.28$, $p = .020$), non-White race ($RR = 0.32$, $p < .001$), history of injection drug use ($RR = 10.16$, $p < .001$), and lack of insurance ($RR = 1.99$, $p < .001$) were significantly associated with infection status. Lack of insurance ($RR = 2.67$, $p = .012$) was the only individual-level factor associated with treatment initiation. Community-level factors associated with treatment initiation were higher rates of poverty ($RR = 1.72$, $p = .027$) and uninsurance ($RR = 1.74$, $p = .023$), while a greater percent of individuals ages 30–44 was associated with less treatment initiation ($RR = 0.47$, $p = .028$).

Conclusions While programs and protocols for care for difficult-to-treat populations exist, understanding the effectiveness for uptake among target populations is necessary. The study demonstrated the utilization of MHC HCV services by the individuals and communities that would most benefit from this type of care. Screening services were

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utilized more by communities that tend to be medically underserved, and HCV infections were identified in groups that are known to be at high risk. Going forward, these findings can be used to direct allocation of MHC HCV resources for targeted intervention.

Keywords Mobile health clinics, Hepatitis C virus, Poverty, Uninsured, Injection drug use

Background

Mobile health clinics (MHC) are a valuable tool for delivery of care to underserved populations including those with barriers to quality healthcare [1–7]. MHCs may offer an especially useful avenue for hepatitis C virus (HCV) screening and treatment, given that many of the primary beneficiaries of MHCs are also those at highest risk of HCV infection such as minority groups, the uninsured, and people with high-risk lifestyles, including people who inject drugs (PWID) [8–13]. HCV is both debilitating, through a risk of liver damage and mortality, as well as highly treatable [14, 15]. However, studies show only 19% of people living with an HCV infection are aware of their infection, and only 15% of diagnosed individuals receive treatment [14]. Protocols have been described for screening and testing through MHCs and linkage to treatment among historically difficult-to-treat populations [16, 17]; in practice, it is unknown whether MHCs are utilized by the most at-risk populations, thereby mitigating existing barriers to HCV care.

Despite being highly treatable, HCV is among the most prevalent infectious diseases, with the population of those unaware of their infection representing a substantial portion of infections [14, 18, 19]. As a result of promising treatment, in 2016, the World Health Organization (WHO) set a goal to eliminate HCV as a public health threat by 2030 [19]. Ideally, anyone with HCV should have access to affordable and effective care to reduce its global burden [19]. That said, those who are most likely to have HCV are also some of those most aggressively hit by disparities and social vulnerabilities [8–13]. Additionally, uptake of care is especially low among uninsured populations and PWID [20–22]. Enhanced strategies to facilitate access to screening, treatment uptake, and treatment completion for these difficult-to-treat, at-risk populations are key towards HCV elimination as a public health threat.

MHCs may be a necessary tool for progression towards elimination. MHCs have documented success in reducing inequality in healthcare based on social determinants of health through offering care to populations that are generally underserved [1]. Additionally, through their mobility and ambition to provide care to underserved populations, MHCs are uniquely positioned to deliver quality healthcare to communities with high risk of HCV infection. Notably, MHCs have been shown to be a key tool for identifying HCV infections among unaware, uninsured, and PWID populations, as well as an acceptable source of HCV screening and treatment initiation among these populations with heightened vulnerabilities and limited uptake [17, 20–23]. As such, MHCs may be necessary for mitigating barriers to HCV care [17]. However, MHCs can be expensive and complicated to operate [1]. Therefore, it is necessary to understand characteristics of those utilizing MHC services in order to examine MHCs' ability to reach the most at-risk and underserved populations and recognize factors that may impact or limit utilization, thereby aiding in allocation of MHC resources.

The purpose of the present study was to examine characteristics that are associated with MHC utilization for HCV screening and infection status. We examined (1) community-level characteristics for HCV screening uptake, HCV infection positivity, and treatment initiation and (2) individual-level characteristics for HCV infection positivity and treatment initiation. We thereby investigated the utility of MHCs for reaching target communities with vulnerability through being underserved (have a need for screening) and for reaching target individuals with high risk of infection (have a need for testing and treatment).

Methods

Setting

Clemson Rural Health (CRH), housed within Clemson University, delivers health services in the Upstate and Midlands regions of South Carolina through four physical facilities and nine mobile health units. CRH aims to serve rural and underserved communities to improve health outcomes in these regions. Since 1995, CRH has been able to serve patients in their own locale through the utilization of MHCs. Through a multidisciplinary team consisting of advanced practice registered nurses (APRNs), registered nurses, health educators, dietitians, social workers, and Spanish translators, the CRH MHC program regularly provides services for preventative screenings, women's health, primary care, health education, and nutrition counseling. The MHC program was expanded in 2016 resulting in partnerships with 31 of 46 counties in South Carolina and more than 25,000 miles of travel per year. Partnerships include local health systems,

state agencies including the Department of Health, health events and free clinics, substance use treatment and rehabilitation facilities, community-serving organizations like soup kitchens and homeless shelters, faith-based organizations, and rural primary care practices. Leveraging of these partnerships allows community organizations to serve as trusted messengers, facilitating trust in CRH, promoting use of MHC services, and providing safe parking at sites [24].

In April 2021, the CRH MHC program began offering HCV screening and treatment to address WHO's 2030 elimination goal. In focusing their efforts in rural and underserved communities, including those with high minority, PWID, and uninsured populations, the CRH MHC program offers insight into predictive characteristics for HCV care uptake through MHCs and MHCs' potential to address care barriers for high-risk individuals. Additional details of the framework for HCV care for all patients, including the uninsured population, are provided elsewhere [17]. Briefly, CRH deploys MHC HCV services in the Upstate and Midland regions to locations of community partners. Following screening, initial testing used rapid antibody testing at no cost to patients. Patients who tested positive were registered into the electronic health record (EHR), including insurance information, when applicable, and MHC APRNs collected the individual's lab for HCV ribonucleic acid (RNA) testing for viral load. Processes that had been set up within the EHR ensured that uninsured patients were not billed for services. At a 1-week follow-up, treatment was initiated for those with an RNA count warranting treatment. MHC staff provided a prescription for the treatment regimen, completed prescription assistance applications, and sent it to the drug company.

Participants

Participants were all individuals screened at a CRH MHC site between May 24, 2021, and January 30, 2024. Any individual visiting the MHC of 18 years of age or older and consenting to screening was eligible to be screened. MHC staff collected descriptive information from these participants when they were screened for HCV. Community-level characteristics were linked to the MHC site location (zip code or census tract level). CRH did not have a role in the recruitment of participants, providing services to any individual who visited the MHC.

Individual- and community-level predictor variables

MHC staff collected basic individual-level descriptive information: age, sex, race, history of injection drug use (IDU), primary mode of transportation to the MHC, insurance status, employment status, sexual activity, and primary care provider (PCP) status. We extracted community-level variables at either the census-tract (United States Census Bureau, Suitland, MD, USA [25]; Centers for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry, Atlanta, GA, USA [26]) or zip-code level (South Carolina Center for Rural and Primary Healthcare, Columbia, SC, USA [27]). Social vulnerability index (SVI) [26], median income, unemployment rate, and labor force participation rate were collected at the census-tract level, as well as census-tract-level distributions of total population, populations for age groups, sex, race, and ethnicity [25]. SVI is a quantitative indicator used to assess the potential risks and vulnerability of communities to the adverse impacts of disasters. It is based on 15 census variables within 4 domains: socioeconomic status, household composition and disability, minority status and language, and housing and transportation [26, 28]. This index serves as a useful tool for identifying communities that are likely to experience disproportionate negative effects in the aftermath of disasters, with higher SVI indicating greater vulnerability. Healthcare access variables of hospital availability (whether or not there is a hospital in the zip code), number of PCP per 1000 residents, uninsured population rate, population rate in poverty, all-cause mortality rate, and percent of rural area were collected at the zip-code level [27].

Outcomes

We explored the relationship between individual- and community-level characteristics and outcomes related to MHC utilization for HCV care. Community-level factors were examined for the outcome of uptake of services through the number of people screened at MHC sites. Community- and individual-level characteristics were examined for the outcomes of HCV test result (binary: infected/not infected) and treatment initiation (binary: initiated/not initiated). HCV infection was defined as a positive antibody test, followed by detected RNA in a viral load laboratory test; and a patient was defined as having initiated treatment if they obtained their first bottle of medication, either through picking it up at the pharmacy or having it delivered by the MHC.

Data analysis

Descriptive statistics were used to describe the study population. Continuous variables were presented as median (interquartile range; IQR) and categorical variables as N (%). Negative binomial generalized linear mixed-effects models (GLMM) were used to examine the association between community-level predictors and utilization of the MHCs for HCV screening. The outcome variable for this analysis was the number of individuals screened at each site visit. Negative binomial GLMMs

were adjusted for study population (census tract population older than 18 years of age), site type, and number of site visits where census tract of MHC site was the random effect. More information on models (Additional File 1) and adjusted variables (Additional File 2: Table S2) is provided in the additional files. The relationship between factors and HCV-related outcomes of HCV infection and treatment uptake was examined with binomial GLMM for the binary outcome of 1 = infection/initiated and 0 = not infection/declined. Factors were independently examined within the models, and models were adjusted for study population and the site type where census tract was the random effect. Continuous variables were standardized to a normal distribution with a mean of zero and a standard deviation of 1 for ease of comparison of results. All analyses were conducted with R software version 4.4.0 (Vienna, Austria [29]).

Results

A total of 1035 individuals were screened at a CRH MHC in the period of May 24, 2021, to January 30, 2024. Descriptive characteristics of screened, infected, and treatment initiated are provided in Table 1. Among those screened, the median age was 43 years of age (*IQR*: 34–56), and most individuals were between 30 and 44 years of age (43%). The majority of individuals were male (57%), non-Hispanic White (68%) followed by non-Hispanic Black (21%), uninsured (51%), unemployed (54%), and did not have a PCP (79%). One-third of the screened population had a history of IDU (34%). One-third of individuals were sexually active (33%), 27% were not sexually active, and 40% did not report about their sexual activity. More than half of individuals used their own vehicle as their primary mode of transportation (54%), with 22% walking, biking, or using a scooter as their primary mode of transportation.

The MHCs visited seven different types of sites (Table 2). A total of 229 visits were done to behavioral health and addiction centers (44%), food banks (20%), law enforcement centers (14%), and homeless services (11%). The average number of visit times to a site location was highest among homeless services (8.7) and behavioral health and addiction centers (8.4) site types. Utilization of services per visit was highest at food banks (median: 4, *IQR*: 2–6) and law enforcement centers (median: 4, *IQR*: 2–13), in contrast to lowest at behavioral health and addiction centers (median: 2, *IQR*: 1–4), homeless services (median: 2, *IQR*: 1–4), and hospitals (median: 2, *IQR*: 1–2).

Community-level factors associated with the utilization of MHC service for HCV screening are shown in Table 3. Negative binomial GLMM model results, including estimated relative risk (RR), 95% confidence interval (CI), and *p*-value, are provided. The estimated coefficients (exponentiated) represent the change in expected MHC screening for a standard-deviation increase in the variable of interest. Census tracts with high poverty rate (*RR*: 1.32, 95% *CI*: 1.06–1.63, $p = .012$) and uninsured rate (*RR*: 1.31, 95% *CI*: 1.10–1.57, $p = .003$) were more likely to utilize MHCs for HCV screening and treatment; census tracts with higher rural areas were less likely to utilize the MHC (*RR*: 0.74, 95% *CI*: 0.56–0.97, $p = .029$).

Results for individual- and community-level factors for the outcomes of HCV infection status and treatment initiation are provided in Table 4. Among individual-level factors, an individual's age, race/ethnicity, history of IDU, and insurance status were significantly associated with infection status. History of IDU showed a particularly strong association: those with IDU were 10.16 times more likely to have a current HCV infection compared to those without injection drug use (95% *CI*: 6.37–16.22, $p < .001$). Additionally, those in the age group of 30–44 were more likely to have a current infection compared to the youngest age group of 18–29 (*RR*: 2.28, 95% *CI*: 1.14–4.55, $p = .019$), as were uninsured individuals compared to insured individuals (*RR*: 1.99, 95% *CI*: 1.34–2.96, $p < .001$). Non-White individuals were less likely than non-Hispanic White individuals to have a current infection (*RR*: 0.32, 95% *CI*: 0.19–0.55, $p < .001$). Lack of insurance was the only factor that was associated with treatment initiation, such that those who were uninsured were more likely to initiate treatment than insured individuals (*RR*: 2.67, 95% *CI*: 1.24–5.74, $p = .012$).

Among community-level factors, there was a lack of association of any variables with HCV positivity. Census tracts with higher poverty (*RR*: 1.72, 95% *CI*: 1.06–2.78, $p = .027$) and uninsurance rate (*RR*: 1.74, 95% *CI*: 1.08–2.81, $p = .023$) were associated with higher treatment initiation, whereas census tracts with higher population aged 30 to 44 were less likely to initiate for treatment (*RR*: 0.47, 95% *CI*: 0.24–0.92, $p = .028$).

Discussion

MHCs, through their mobility and effort to reach difficult-to-treat populations, seem an appropriate tool for HCV screening, testing, and treatment services. The present study sought to examine whether MHCs (1) reach target communities for vulnerability through being underserved and, therefore, have a need for screening and (2) reach target individuals for HCV risk and, therefore, have a need for testing and treatment. We investigated community-level predictors of MHC utilization for HCV services in an effort to understand their utility in reaching the most vulnerable and at-risk populations. The results showed that the MHCs' HCV screening services were utilized by underserved communities. Additionally,

Table 1 Descriptive statistics for screened population, individuals who had a current HCV infection detected through viral load test, and individuals who initiated treatment

	Utilized MHC (*N* = 1035)	**HCV positive (*N* = 154)**	**Initiated treatment (*N* = 125)**
Age, median (IQR)	43 (34–56)	40 (34–51)	40 (34–51)
Age group, *N* (%)			
18–29	108 (10.3)	11 (7.1)	11 (8.8)
30–44	449 (43.4)	86 (55.9)	70 (56.0)
45–64	368 (35.6)	48 (31.2)	40 (32.0)
65 and over	103 (10.0)	8 (5.2)	4 (3.2)
Unknown	7 (0.7)	1 (0.6)	
Sex, *N* (%)			
Male	590 (57.0)	99 (64.3)	79 (63.2)
Female	443 (42.8)	55 (35.7)	46 (36.8)
Unknown	2 (0.2)		
Race, *N* (%)			
Black	220 (21.3)	19 (12.4)	13 (10.4)
Hispanic/Latino	87 (8.4)	1 (0.6)	1 (0.8)
White	702 (67.8)	133 (86.4)	110 (88.0)
Other	10 (1.0)	1 (0.6)	1 (0.8)
Unknown	16 (1.5)		
Insurance status, *N* (%)			
Private	424 (41.0)	43 (27.9)	28 (22.4)
Medicaid/Medicare	14 (1.3)	6 (3.9)	3 (2.4)
Uninsured	528 (51.0)	102 (66.3)	92 (73.6)
Unknown	69 (6.7)	3 (1.9)	2 (1.6)
Transport type, *N* (%)			
Car	563 (54.4)	78 (50.6)	62 (49.6)
Bike	24 (2.3)	7 (4.6)	4 (3.2)
Scooter	10 (1.0)	1 (0.6)	2 (1.6)
Walk	190 (18.4)	32 (20.8)	26 (20.8)
Public transportation	63 (6.0)	10 (6.5)	9 (7.2)
Other	43 (4.2)	7 (4.6)	5 (4.0)
Unknown	142 (13.7)	19 (12.3)	17 (13.6)
Employment status, *N* (%)			
Employed	340 (32.9)	43 (27.9)	39 (31.2)
Unemployed	558 (53.9)	106 (68.9)	80 (64.0)
Retired	44 (4.2)	2 (1.3)	2 (1.6)
Unknown	93 (9.0)	3 (1.9)	4 (3.2)
Sexual activity, *N* (%)			
Active	341 (32.9)	55 (35.7)	47 (37.6)
Not active	281 (27.2)	47 (30.5)	39 (31.2)
Unknown	413 (39.9)	52 (33.8)	39 (31.2)
Injection drug use, *N* (%)			
Yes	353 (34.1)	116 (75.3)	100 (80.0)
No	562 (54.3)	30 (19.5)	22 (17.6)
Unknown	120 (11.6)	8 (5.2)	3 (2.4)
PCP status, *N* (%)			
Yes	196 (18.9)	26 (16.9)	22 (17.6)
No	820 (79.2)	121 (78.6)	101 (80.8)
Unknown	19 (1.9)	7 (4.5)	2 (1.6)

MHC mobile health clinic; *PCP* primary care provider; *HCV* hepatitis C virus

Table 2 Average number of site visits conducted to a site location and median individuals utilizing MHC services per site visit based on different site types

Site type	Total number of visits	Average number of visits to a site	Median (IQR) uptake per site visit
Behavioral health/addiction centers	101	8.4	2 (1–4)
Community health resources/free clinics	8	1.1	3 (1–7)
Faith-based organizations	8	2.0	3 (1–10)
Food banks	45	6.4	4 (2–6)
Homeless services	26	8.7	2 (1–4)
Hospitals	8	2.0	2 (1–2)
Law enforcement centers	33	4.1	4 (2–13)

MHC mobile health clinics; *IQR* interquartile range

Table 3 Community-level factors related to mobile health clinic screening utilization

Community-level factors	RR	95% *CI*	*p*-value
Percent age 30–44	1.01	0.64–1.59	.964
Percent age 45–65	1.00	0.63–1.61	.988
Percent age over 65	1.08	0.73–1.58	.702
Percent male	1.05	0.76–1.46	.746
Percent Black	0.96	0.68–1.36	.819
Percent Other	1.21	0.90–1.62	.207
Percent Hispanic	1.27	0.87–1.83	.213
Social vulnerability index	0.94	0.67–1.34	.747
Income	0.99	0.68–1.42	.939
Percent rural area	0.74	0.56–0.97	.029
Percent in poverty	1.32	1.06–1.63	.012
Unemployment rate	0.79	0.55–1.12	.185
Labor force participation	1.22	0.88–1.70	.234
PCP rate	0.95	0.63–1.42	.800
Hospital presence	0.99	0.48–2.05	.974
Uninsurance rate	1.31	1.10–1.57	.003
Mortality rate	0.90	0.65–1.23	.496

RR relative risk; *CI* confidence interval; *PCP* primary care provider; *HCV* hepatitis C virus

HCV testing services detected cases among individuals at high risk of HCV infection. The findings indicate that, in practice, MHCs may serve as useful tools for mitigating existing barriers to HCV care through demonstrated utilization by communities and individuals that can most benefit from enhanced care.

The individuals who utilized MHC services and consented to screening for HCV were from underserved communities who tend to experience barriers to care. Specifically, individuals from communities with a higher rate of poverty and higher rate of uninsured persons were more likely to utilize HCV screening services. On the other hand, while their ability to mitigate geographical burdens to healthcare, such as rurality, is considered a benefit of MHCs [1, 30–32], greater rurality was associated with less uptake of services. Communities with greater rurality may have less ability to get to the MHCs, either due to transportation circumstances or distance, and rural areas provide less centralized and stable sites for the MHCs to park. MHC programs that aim to specifically serve highly rural areas may have to deliberately target these areas [32] and also expect that uptake may not be as high or efficient in these communities. Programs aiming to distribute resources most effectively may need to focus on specific community factors, in this case communities particularly affected by poverty and lack of insurance, as most indicative of HCV screening uptake services. These communities should be a priority for HCV screening, such that MHCs may be the best, or only, avenue for HCV care and identification of potential infections among individuals who would otherwise be unaware.

Community-level and individual-level factors demonstrated use by those most in need of testing and treatment. The individual-level factors that were associated with HCV infection status were consistent with characteristics of individuals at high risk for HCV. Individuals who tend to be disproportionally affected by HCV are those with low socioeconomic status, minority populations, and uninsured populations [8–10]. Given that HCV is highly transmittable through IDU, PWID are also at high risk of HCV infection [11, 33–35]. The results showed that those with IDU were especially likely to have a current HCV infection, followed by those ages 30–44 and minority individuals. While we did not specifically examine community-level IDU, higher rates of poverty and lower socioeconomic status are associated with greater likelihood of drug use, including injecting drugs [36, 37]. Therefore, communities with greater poverty,

Table 4 Individual-level and community-level results for HCV infection status and treatment initiation

	HCV positive			Initiated treatment		
Variables	**RR**	**CI**	***p*-value**	**RR**	**CI**	***p*-value**
Individual-level factors						
Age (18–29)						
Age 30–44	2.28	1.14–4.55	.019	1.60	0.42–6.10	.494
Age 45–65	1.56	0.75–3.24	.232	1.49	0.36–6.29	.584
Age over 65	1.04	0.37–2.91	.938	0.59	0.08–4.27	.599
Male (female)	1.32	0.90–1.94	.150	0.60	0.28–1.30	.200
Non-white (White)	0.32	0.19–0.55	< .001	0.41	0.13–1.28	.123
Injection drug use (not user)	10.16	6.37–16.22	< .001	2.37	0.99–5.69	.053
Uninsured (insured)	1.99	1.34–2.96	< .001	2.67	1.24–5.74	.012
Transportation (car)						
Bike, scooter, or walk	1.40	0.85–2.31	.187	1.22	0.45–3.30	.702
Public transportation	1.20	0.56–2.58	.635	1.14	0.25–5.25	.864
Other	1.00	0.38–2.62	.993	0.72	0.14–3.60	.691
Not employed (employed)	1.40	0.93–2.11	.107	0.53	0.23–1.23	.140
Sexually active (not active)	0.86	0.55–1.37	.531	0.75	0.30–1.84	.523
Community-level factors						
Percent age 30–44	1.15	0.63–2.09	.658	0.47	0.24–0.92	.028
Percent age 45–65	0.75	0.39–1.45	.390	0.85	0.43–1.70	.648
Percent age over 65	1.29	0.79–2.09	.304	1.08	0.69–1.68	.736
Percent male	1.27	0.79–2.03	.323	0.89	0.65–1.23	.495
Percent Black	1.10	0.63–1.90	.741	0.75	0.45–1.27	.290
Percent Other	0.78	0.49–1.24	.294	0.44	0.10–1.85	.260
Percent Hispanic	0.84	0.48–1.48	.552	1.15	0.80–1.66	.446
Social vulnerability index	1.34	0.81–2.21	.259	1.03	0.68–1.56	.898
Income	0.85	0.50–1.43	.536	0.90	0.58–1.39	.645
Percent rural area	0.79	0.49–1.28	.333	1.63	0.95–2.79	.073
Percent in poverty	0.79	0.49–1.25	.314	1.72	1.06–2.78	.027
Unemployment rate	1.10	0.69–1.78	.682	1.27	0.84–1.92	.252
Labor force participation	0.75	0.48–1.18	.220	0.87	0.58–1.32	.522
PCP rate	1.47	0.83–2.59	.185	0.99	0.62–1.57	.964
Hospital presence	2.06	0.76–5.59	.154	0.56	0.25–1.25	.155
Uninsurance rate	0.74	0.46–1.20	.226	1.74	1.08–2.81	.023
Mortality rate	0.89	0.62–1.26	.506	1.10	0.78–1.55	.592

Values in parentheses are reference categories

RR relative risk; *CI* confidence interval; *PCP* primary care physician; *HCV* hepatitis C virus

identified in our community-level analysis, may coincide with high rates of IDU, identified in our individual-level analysis. Collectively, given utilization of the MHC among at-risk individuals, it may be a key tool for identification of cases among difficult-to-treat populations.

Additionally, insurance status was a key factor in both the community-level analysis and the individual-level analysis. There was evidence of success for the MHC program's aim of delivering care regardless of insurance status, as a higher percentage of uninsured individuals at the community level and an individual's own uninsured status were both associated with HCV infection. In fact, the uninsured population may encompass a disproportionately high number of the 81% of HCV-infected individuals who are unaware of their infection status [9, 14]. Lack of insurance was also the only individual-level factor that was associated with treatment initiation, while high rates of poverty and lack of insurance at the community level were also associated with treatment initiation. In the general health services setting, those without insurance face financial barriers, among others, to care that lead to less utilization of healthcare services than those with insurance, particularly for treatment uptake [38–40]. On the other hand, when a setting such as the MHC with special

protocols for the uninsured is available, the uninsured likely face less barriers to care than those with insurance, such as high out-of-pocket costs and more requirements for obtaining treatment. Therefore, these findings indicate that the MHCs are not only identifying cases in medically underserved and vulnerable populations but also mitigating barriers to treatment in communities facing high poverty and lack of insurance. The MHC program's ability to reach and have its HCV services utilized by these populations may be a crucial use of MHCs for HCV elimination as a public health threat.

The results of this study can guide identification of cases and treatment efforts for HCV elimination. Primarily, the results demonstrated the utility of an MHC HCV program for reaching target populations, both through communities that are medically underserved and in need of access to screening and through individuals who are at high risk of HCV infection. Furthermore, identification of community-level and individual-level predictive factors of such utilization can guide allocation of future MHC sites. Specifically, mapping that utilizes the community-level factors identified here of screening uptake can help identify underserved communities that are most likely to utilize HCV screening services. Furthermore, site types for MHC visits showed variation in utilization efficiency. Notably, while IDU is a major predictor of HCV infection, behavioral health and addiction center sites, the most frequently visited site type by the MHC, did not show the greatest uptake of services per MHC visit. Food banks and law enforcement centers showed greater utilization per visit. Collectively, understanding of factors related to total utilization, cases, and treatment initiation can drive allocation of community-based resources for MHC HCV services.

The present study has limitations. MHCs can be difficult to finance, as can care for uninsured individuals [1]. The CRH MHC program mitigated these challenges through external funding both for the MHC program and additional funding to specifically provide care for uninsured individuals. Programs aiming to implement similar protocols would likely need to also secure funding. MHCs do, however, have the benefit of being able to provide prevention services, such as testing for HCV, to which that rural and underserved communities likely do not have access. In this way, the CRH MHCs may ultimately be a cost-efficient option mitigating the likelihood that lack of detection of illness would lead to serious disease (e.g., end-stage liver disease) that requires costly treatment [41, 42]. An analysis of the cost savings from the CRH MHC program is planned future research. Additionally, the community-level and individual-level predictors identified here may be specific to the Upstate and Midlands regions of South Carolina. Programs in other areas of the state or nation should perform similar analyses to extract relevant predictors of utilization of MHC-delivered HCV services in their target area. That said, given that the MHCs travel to a variety of locations in South Carolina, generalizability may be enhanced by variance in characteristics of the population across the state. Furthermore, uptake of programs may be influenced by marketing strategies, which were not assessed in this study. Community organizations, through being trusted messengers, can promote the MHCs, putting emphasis on the necessity of MHCs to have partnerships that can act as marketers for public health services [24]. Therefore, in order to allocate resources to areas that can benefit most from services, MHCs must maintain focus on building relationships and partnerships with community organizations in targeted areas. Future studies could incorporate qualitative interviews with individuals visiting the site to gather more information about how to influence effective utilization. Finally, additional factors may be of interest or relevant in future studies, including individual-level details such as migrant worker status, behavioral risk factors, and comorbidities of human immunodeficiency virus and hepatitis B virus.

Conclusions

HCV is a highly treatable disease that, with targeted healthcare towards unaware, at-risk communities and individuals, can be eliminated as a public health threat. MHCs, through their ability to reach medically underserved and high-risk populations, seem to be an important fit for mitigating barriers to HCV care. While programs and protocols for care for difficult-to-treat populations exist, understanding of the effectiveness of such programs for uptake among target populations is necessary. Through evidenced utilization of screening services by communities with high rates of poverty and high rates of uninsured persons, the study demonstrated uptake of screening services by communities that tend to be medically underserved, for whom the MHC may be one of the only sources of HCV screening. High rates of poverty and lack of insurance at the community level were also associated with HCV infection and treatment initiation, demonstrating the MHC's utility as a tool towards identification of cases and facilitator of treatment. At the individual level, HCV infections were identified in groups that are known to be at high risk, including PWID and individuals who are uninsured. Therefore, collectively, the study showed utilization of MHC HCV services by the demographics that would most benefit from this type of care. These results can be used to direct allocation of MHC HCV resources for targeted intervention among underserved and vulnerable communities and individuals.

Abbreviations

APRN	Advanced practice registered nurse
CI	Confidence interval
CRH	Clemson Rural Health
EHR	Electronic health record
GLMM	Generalized linear mixed-effects model
HCV	Hepatitis C virus
IDU	Injection drug use
IQR	Interquartile range
MHC	Mobile health clinic
PCP	Primary care provider
PWID	People who inject drugs
RNA	Ribonucleic acid
RR	Relative risk
SVI	Social vulnerability index
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s44263-024-00114-w.

Additional file 1: Model Descriptions. Description of the models used in the study, including negative binomial GLMM for site data analysis on MHC utilization and logistic GLMM for individual data analysis on MHC utilization.

Additional file 2: Information on Adjusted Factors. Information on factors that the models adjusted for and the results of their association with MHC utilization. Table S1: Results for adjusted factors in the negative binomial and binomial models.

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Author' contributions
LR and KAH conceptualized this paper and developed the methodology for the manuscript. KAH and FG drafted the original manuscript. LR performed project administration. CAM, PR, AC, KB, RWG, and AHL performed the investigation described in this manuscript and acquired the data. FG and AB performed data analysis. CAM, FG, BW, AB, and KB verified the data underlying this study. KAH, FG, BW, and LR interpreted the data for the work. CAM and AHL acquired funding. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. The data provided in this manuscript is aggregate and the results of statistical modeling. Individual-level records are not available due to patient confidentiality. R code, an aggregated dataset, or a limited dataset in which all cells have $N > 5$ can be made available upon reasonable request from the corresponding authors at khowar7@clemson.edu or liorr@clemson.edu.

Declarations

Ethics approval and consent to participate
Clemson Rural Health mobile health clinic operations deferred to an approved application by the Prisma Health Institutional Review Board (IRB Pro00106348). Written consent was obtained from all patients. Patients signed a consent form at their MHC visits that included consent for studies evaluating the utility of the program. The study conformed to the ethical principles of the Helsinki Declaration for the protection of participants.

Consent for publication
Not applicable.

Competing interests
AHL has served on the advisory boards for Gilead Sciences, Inc., and AbbVie. The remaining authors declare no competing interests.

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References

1. Yu SWY, Hill C, Ricks ML, Bennet J, Oriol NE. The scope and impact of mobile health clinics in the United States: a literature review. Int J Equity Health. 2017;16(1):178.
2. Malone NC, Williams MM, Smith Fawzi MC, Bennet J, Hill C, Katz JN, et al. Mobile health clinics in the United States. Int J Equity Health. 2020;19(1):40.
3. Schwitters A, Lederer P, Zilversmit L, Gudo PS, Ramiro I, Cumba L, et al. Barriers to health care in rural Mozambique: a rapid ethnographic assessment of planned mobile health clinics for ART. Glob Health Sci Pract. 2015;3(1):109–16.
4. Alvi RA, Justason L, Liotta C, Martinez-Helfman S, Dennis K, Croker SP, et al. The Eagles Eye Mobile: assessing its ability to deliver eye care in a high-risk community. J Pediatr Ophthalmol Strabismus. 2015;52(2):98–105.
5. Nuttbrock L, Rosenblum A, Magura S, McQuistion H. Broadening perspectives on mobile medical outreach to homeless people. J Health Care Poor Underserved. 2003;14(1):5–16.
6. Thomas CM, Liebman AK, Galván A, Kirsch JD, Stauffer WM. Ensuring COVID-19 vaccines for migrant and immigrant farmworkers. Am J Trop Med Hyg. 2021;104(6):1963–5.
7. Hill C, Zurakowski D, Bennet J, Walker-White R, Osman JL, Quarles A, et al. Knowledgeable neighbors: a mobile clinic model for disease prevention and screening in underserved communities. Am J Public Health. 2012;102(3):406–10.
8. Khalili M, Wong RJ. Underserved does not mean undeserved: unfurling the HCV Care in the Safety Net. Dig Dis Sci. 2018;63(12):3250–2.
9. Ong JP, Collantes R, Pitts A, Martin L, Sheridan M, Younossi ZM. High rates of uninsured among HCV-positive individuals. J Clin Gastroenterol. 2005;39(9):826–30.
10. Beck KR, Kim NJ, Khalili M. Direct acting antivirals improve HCV treatment initiation and adherence among underserved African Americans. Ann Hepatol. 2018;17(3):413–8.
11. Martin NK, Vickerman P, Dore GJ, Hickman M. The hepatitis C virus epidemics in key populations (including people who inject drugs, prisoners and MSM): the use of direct-acting antivirals as treatment for prevention. Curr Opin HIV AIDS. 2015;10(5):374–80.

12. Arum C, Fraser H, Artenie AA, Bivegete S, Trickey A, Alary M, et al. Homelessness, unstable housing, and risk of HIV and hepatitis C virus acquisition among people who inject drugs: a systematic review and meta-analysis. Lancet Public Health. 2021;6(5):e309–23.
13. Bruggmann P. Accessing hepatitis C patients who are difficult to reach: it is time to overcome barriers. J Viral Hepat. 2012;19(12):829–35.
14. Stasi C, Silvestri C, Voller F. Update on hepatitis C epidemiology: unaware and untreated infected population could be the key to elimination. SN Compr Clin Med. 2020;2(12):2808–15.
15. Sandmann L, Schulte B, Manns MP, Maasoumy B. Treatment of chronic hepatitis C: efficacy, side effects and complications. Visc Med. 2019;35(3):161–70.
16. Lazarus JV, Øvrehus A, Demant J, Krohn-Dehli L, Weis N. The Copenhagen test and treat hepatitis C in a mobile clinic study: a protocol for an intervention study to enhance the HCV cascade of care for people who inject drugs (T'N'T HepC). BMJ Open. 2020;10(11): e039724.
17. Rennert L, Howard KA, Kickham CM, Gezer F, Coleman A, Roth P, et al. Implementation of a mobile health clinic framework for hepatitis C virus screening and treatment: a descriptive study. Lancet Reg Health - Am. 2024;29: 100648.
18. Havens PL, Anderson JR. Updated CDC recommendations for universal hepatitis C virus screening among adults and pregnant women: implications for clinical practice. JAMA. 2020;323(22):2258.
19. World Health Organization. Global health sector strategy on viral hepatitis, 2016–2021: towards ending hepatitis. [Internet]. Geneva, Switzerland; 2016 [cited 2023 Feb 20]. Available from: https://apps.who.int/iris/bitstream/handle/10665/246177/WHO-HIV-2016.06-eng.pdf;jsessionid=C218A471F69D97C680E0940470EB5455?sequence=1
20. Mehta SH, Genberg BL, Astemborski J, Kavasery R, Kirk GD, Vlahov D, et al. Limited uptake of hepatitis C treatment among injection drug users. J Community Health. 2007;33(3):126.
21. Friedman E. Health insurance, the uninsured, and hospitals: collision course. Front Health Serv Manag. 2005;21(4):3–15.
22. Ditah I, Al Bawardy B, Gonzalez HC, Saberi B, Ditah C, Kamath PS, et al. Lack of health insurance limits the benefits of hepatitis C virus screening: insights from the National Health and Nutrition Examination Hepatitis C Follow-Up Study. Am J Gastroenterol. 2015;110(8):1126–33.
23. Grieb SM, Harris R, Rosecrans A, Zook K, Sherman SG, Greenbaum A, et al. Awareness, perception and utilization of a mobile health clinic by people who use drugs. Ann Med. 2022;54(1):138–49.
24. Shen AK, Browne S, Srivastava T, Kornides ML, Tan ASL. Trusted messengers and trusted messages: the role for community-based organizations in promoting COVID-19 and routine immunizations. Vaccine. 2023;41(12):1994–2002.
25. United States Census Bureau. Explore Census Data [Internet]. Available from: https://data.census.gov/.
26. Agency for Toxic Substances and Disease Registry. CDC/ATSDR SVI Data and Documentation Download [Internet]. 2022. Available from: https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html.
27. University of South Carolina School of Medicine Columbia. South Carolina Rural Healthcare Resource Dashboard [Internet]. Available from: https://sc.edu/study/colleges_schools/medicine/centers_and_institutes_new/center_for_rural_and_primary_healthcare/research/rural_healthcare_dashboard/index.php.
28. Flanagan BE, Gregory EW, Hallisey EJ, Heitgerd JL, Lewis B. A social vulnerability index for disaster management. J Homel Secur Emerg Manag. 2011;8(1).
29. R Core Team (2024). R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
30. De Jesus D-P, Farley T, Cabanis CM. A program to improve access to health care among Mexican immigrants in rural Colorado. J Rural Health. 2004;20(3):258–64.
31. Bodenheimer TS. Mobile units: a solution to the rural health problem?: Med Care. 1969;7(2):144–54.
32. Harris D, Hamel L, Aboueissa AM, Johnson D. A cardiovascular disease risk factor screening program designed to reach rural residents of Maine, USA. Rural Remote Health. 2011;11(3):1–15.
33. Day E, Hellard M, Treloar C, Bruneau J, Martin NK, Øvrehus A, et al. Hepatitis C elimination among people who inject drugs: challenges and recommendations for action within a health systems framework. Liver Int. 2019;39(1):20–30.
34. Treloar C, Rance J, Backmund M. Understanding barriers to hepatitis C virus care and stigmatization from a social perspective. Clin Infect Dis. 2013;57(suppl_2):S51–5.
35. Frankova S, Jandova Z, Jinochova G, Kreidlova M, Merta D, Sperl J. Therapy of chronic hepatitis C in people who inject drugs: focus on adherence. Harm Reduct J. 2021;18(1):69.
36. Baptiste-Roberts K, Hossain M. Socioeconomic disparities and self-reported substance abuse-related problems. Addict Health. 2018;10(2).
37. Nandi A, Glass TA, Cole SR, Chu H, Galea S, Celentano DD, et al. Neighborhood poverty and injection cessation in a sample of injection drug users. Am J Epidemiol. 2010;171(4):391–8.
38. Choi NG, DiNitto DM, Choi BY. Unmet healthcare needs and healthcare access gaps among uninsured U.S. adults aged 50–64. Int J Environ Res Public Health. 2020;17(8):2711.
39. Kamimura A, Panahi S, Ahmmad Z, Pye M, Ashby J. Transportation and other nonfinancial barriers among uninsured primary care patients. Health Serv Res Manag Epidemiol. 2018;1:5.
40. Zhou RA, Baicker K, Taubman S, Finkelstein AN. The uninsured do not use the emergency department more—they use other care less. Health Aff (Millwood). 2017;36(12):2115–22.
41. Attipoe-Dorcoo S, Delgado R, Lai D, Gupta A, Linder S. Analysis of annual costs of mobile clinics in the Southern United States. J Prim Care Community Health. 2020;11.
42. Song Z, Hill C, Bennet J, Vavasis A, Oriol NE. Mobile clinic in Massachusetts associated with cost savings from lowering blood pressure and emergency department use. Health Aff (Millwood). 2013;32(1):36–44.

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