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RESEARCH ARTICLE

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Incidence and prevalence of antibody to hepatitis C virus in FDNY first responders before and after work at the World Trade Center disaster site

Mayris P. Webber DrPH, MPH[1,2] | Yang Liu MS[2] | Hillel W. Cohen DrPH, MPH[1] | Theresa Schwartz MS[2] | Michael D. Weiden MD[2] | Kerry Kelly MD[2] | Viola Ortiz MD[2] | Rachel Zeig-Owens DrPH, MPH[1,2] | Nadia Jaber RPA-C[2] | Hilary L. Colbeth MPH[2] | David J. Prezant MD[2,3]

[1] Department of Epidemiology and Population Health, Montefiore Medical Center and Albert Einstein College of Medicine, Bronx, New York

[2] Fire Department of the City of New York, Bureau of Health Services, Brooklyn, New York

[3] Pulmonology Division, Department of Medicine, Montefiore Medical Center and Albert Einstein College of Medicine, Bronx, New York

Correspondence
Mayris P. Webber, DrPH, MPH, Fire Department of the City of New York, Bureau of Health Services, 9 Metrotech Center, 5E61 K, Brooklyn, NY 11201.
Email: mayris.webber@fdny.nyc.gov

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Background: The goals of this study were to assess the impact of work at the World Trade Center (WTC) site in relation to new, post-9/11/2001 (9/11) antibody to hepatitis C Virus (anti-HCV); and, evaluate secular trends in WTC-exposed male Fire Department of New York City (FDNY) Firefighters and Emergency Medical Services (EMS) responders.

Methods: FDNY monitors responder health through physical exams and routine blood work. We used descriptive statistics to compare trans-9/11 and post-9/11 incidence and to assess trends in prevalence from 2000 to 2012.

Results: Trans-9/11 incidence of new anti-HCV was 0.42 per 100 persons compared with post-9/11 incidence of 0.34 ($P = 0.68$). Overall seroprevalence was 1.3%; rates declined from 1.79 per 100 to 0.49 per 100 over time ($P < 0.0001$).

Conclusions: Work at the WTC was not associated with new infection. Biennial seroprevalence in responders declined over time, supporting the FDNY decision to discontinue routine annual testing in this cohort.

KEYWORDS
firefighters, hepatitis C, incidence, prevalence, World Trade Center

1 | INTRODUCTION

Firefighters and emergency medical service (EMS) workers routinely respond to fires, non-fire emergencies and medical emergencies.[1] Most previous studies have reported that these workers have rates of hepatitis C virus (HCV) infection comparable to rates in the general population,[2] although it has been suggested that paramedics, the advanced providers among EMS, may have higher rates that are more similar to hospital-based health workers.[3,4] HCV infection spreads primarily through contact with contaminated blood. Accordingly, the risk of infection is increased in those who are current or former injection drug users, receipients of blood transfusions, chronic hemodialysis patients, persons with HIV infection, and health care workers after needle sticks involving HCV-positive blood.[5] In 2001, the CDC reported incident infection among known HCV-exposed health workers as 1.8% (0-10%).[6] However, recently a 13-year longitudinal study among hospital-based health workers with known HCV exposure reported a much lower seroconversion rate of 0.1%.[7]

Terrorist events, such as the World Trade Center (WTC) attacks, present unique challenges to responders who can be exposed to both

Institution at which the work was performed: Fire Department of the City of New York.

direct terrorist threats and indirect threats from environmental hazards such as airborne particles, structural collapses, fires, psychological stress and blood-borne pathogens.[8] A relatively low HCV prevalence among firefighters and EMS performing their usual duties does not preclude the possibility of a spike in blood-borne infections in relation to work at mass casualty events, based on the particulars of the disaster.

The Fire Department of the City of New York (FDNY) World Trade Center (WTC)-exposed cohort of firefighters and EMS workers was the single most affected worker group in NYC, losing 343 responders on 9/11/2001(9/11) and more than 150 responders since, primarily from lung diseases and cancer.[9] After the initial effort at the WTC site, FDNY responders remained involved in rescue and recovery work for up to 10 months, during which time many were exposed to environmental hazards including tons of aerosolized dust, concrete, and glass shards. Further, during this period about one-third of the FDNY cohort reported contact with bodies or body parts (unpublished data). While much is known about post-9/11 health conditions in responders,[10–15] the consequences of exposure to blood-borne pathogens from human remains have not been reported. This is especially important as HCV infection lacks an effective vaccine, is the most common chronic blood-borne infection in the US,[16] and is a leading cause of chronic liver disease such as cirrhosis.[5] Since infection is often asymptomatic,[17] it has been estimated that more than half of HCV-infected US adults are unaware of their infection status.[18] Knowing one's HCV status is especially important because since 2013,[19] effective treatment is available to prevent the potentially life-threatening consequences of chronic liver disease.

The primary goals of the current study were to (i) examine whether work at the WTC site was associated with new, incident infection as evidenced by antibody to HCV (anti-HCV) in the WTC-exposed FDNY cohort; and (ii) estimate the anti-HCV prevalence in 2 year intervals from 2000 to 2012, the period during which anti-HCV tests were routinely performed at FDNY as part of medical monitoring.

2 | METHODS

2.1 | FDNY WTC health program

The mission of the Bureau of Health Services (BHS) at FDNY is to oversee the health of the active workforce of firefighters and EMS, particularly as it affects fitness for duty after an illness, injury, or exposure. Shortly after 9/11, the FDNY-BHS mission expanded to include ongoing surveillance and treatment of FDNY responders, both active and retired, who worked at the WTC site. Based on the annual medical examination for firefighters designed by the International Association of Firefighters Wellness/Fitness Initiative[20] and endorsed by the National Fire Protection Association's Standard on Comprehensive Occupational Medical Program for Fire Departments,[21] the FDNY medical monitoring visit includes physical exams with routine blood tests (Complete Blood Counts (CBCs), SMA-20 chemistry screens including liver panels, and urine analysis) and self-administered physical and mental health questionnaires. Shortly after 9/11 the questionnaires were expanded to include history of WTC exposure. WTC exposure was defined from the earliest post-9/11 health questionnaire and categorized into the following groups: arriving on the morning of 9/11 (arrival group 1; highest level of exposure); arriving after noon of 9/11 (arrival group 2); arriving on 9/12/2001 (arrival group 3); arriving between 9/13/2001 and 9/24/2001 (arrival group 4),[22] and arriving between 9/25/2001, and 7/25/2002 (arrival group 5). Duration of WTC exposure was defined as the number of months a member worked at the WTC site between 9/11 and 7/25/2002 for at least 1 day (range 1-10).[13] Demographic and other information (ie, work assignment as firefighter or EMS) came from the FDNY database.

From 2000 to 2012, blood specimens from all employees who came to BHS for monitoring were screened for anti-HCV; results were captured electronically. After 2012, anti-HCV screening was limited to new hires and to workers who were exposed to blood during the performance of their duties. Therefore, this study limited analyses to bloods drawn for routine surveillance from 1/14/2000-12/31/2012. No specific risk assessment for HCV infection was performed because the self-administered questionnaires conducted during routine FDNY-WTC Health Program visits do not include questions regarding injection or other illicit drug use, sexual behavior, or other activities thought to increase the risk of HCV infection. IRB approval was obtained from the Montefiore Medical Center/Albert Einstein College of Medicine. Written consent was obtained from all study participants.

2.2 | Laboratory

Laboratory test dates and results included anti-HCV, HCV RNA quantitative level, and liver function tests (transaminases, alkaline phosphatase, and bilirubin). Since confirmatory test results were not always available to us through our commercial laboratory contract, we estimated the number of infected workers based on the proportion of confirmed anti-HCV positives among those with a confirmatory test.

2.3 | Study populations

2.3.1 | Incidence cohort

We estimated incidence rates of seroconversion in men during two time periods, trans-9/11 [1/14/2000 to 9/10/2002] ($n = 2867$) and post-9/11 [9/11/2002 to 1/23/2004] ($n = 1491$). Seroconversion during the post-9/11 period (9/11/2002-1/23/2004) is unrelated to work at the WTC, and therefore, serves as a comparison or background rate for the trans-9/11 seroconversion rate. The early period (trans-9/11) is shown in Figure 1A. The population for trans-9/11 seroconversion consisted of those who tested anti-HCV negative pre-9/11 ($n = 814$) or those without a pre-9/11 anti-HCV test, but who had liver function tests at either normal or low levels pre-9/11 ($n = 2053$), totaling 2867 individuals. We used test information from the first post-9/11 test to calculate seroconversion

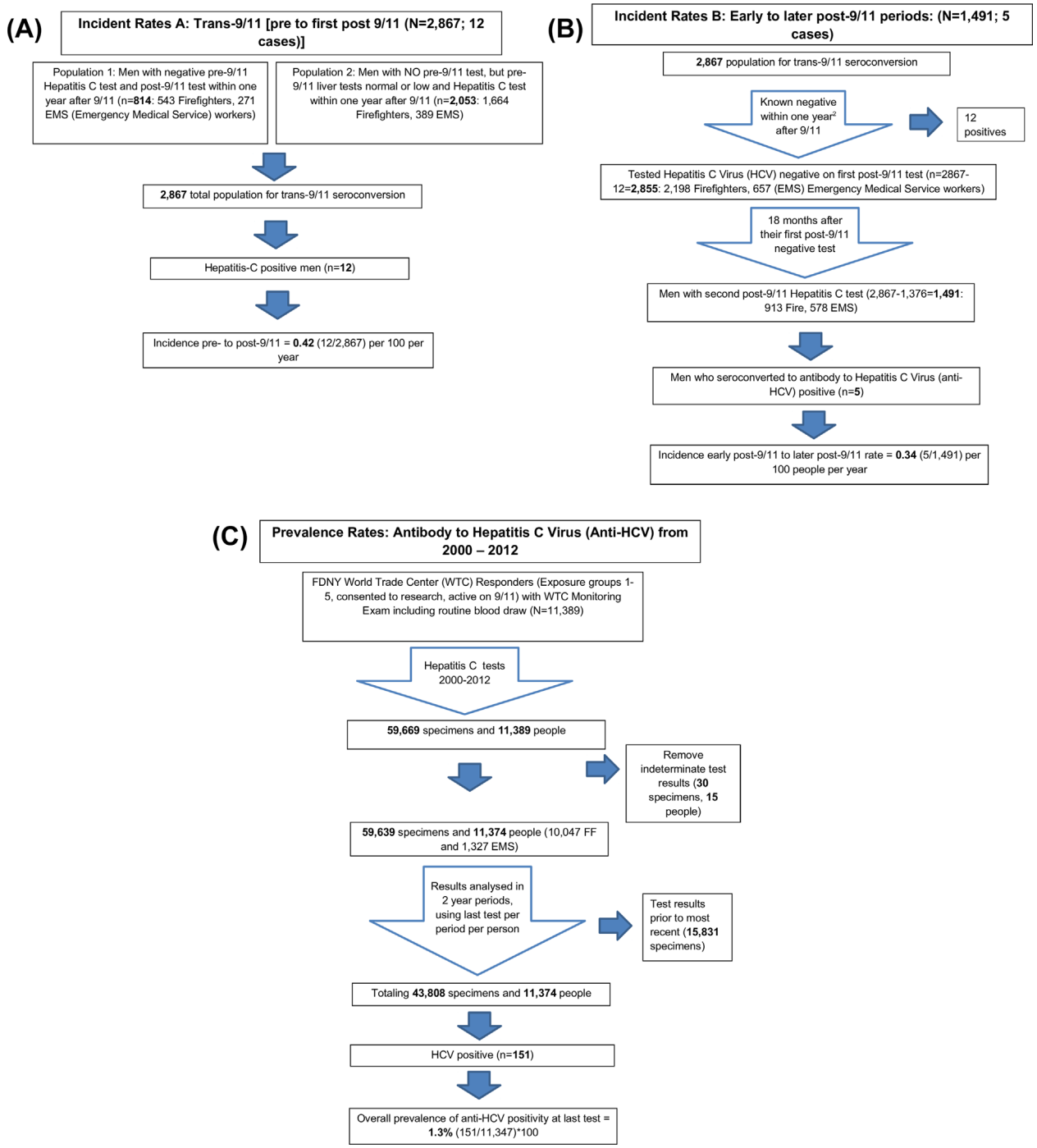

FIGURE 1 A, Population for trans-9/11 incidence study. B, Population for post-9/11 incidence study. C, population for 9/11 prevalence study [Color figure can be viewed at wileyonlinelibrary.com]

rates. On average, the time elapsed between the pre-9/11 test and the first post-9/11 test was 18 months.

The population for the later period (post-9/11) is shown in Figure 1B. The population for the post-9/11 seroconversion consisted of the subset of men in the trans-9/11 cohort who were known to be negative at their first post-9/11 test (n = 2867-12 positives = 2855). The group was further limited to those who also had a second post-9/11 HCV test result within 18 months after their negative first post-9/11 test (n = 1491).

2.3.2 | Prevalence cohort

The prevalence cohort included 11,389 WTC-exposed male firefighters and EMS workers who came to FDNY for medical monitoring between 1/14/2000 and 12/31/2012 and had routine blood tests performed as part of their visit (Figure 1C). We excluded data from 15 whose anti-HCV test results were indeterminate; the final population included 11 374 men.

We calculated the 2-year serial prevalence rates of anti-HCV antibody for 2000-2012 by using all anti-HCV test results from bloods

drawn during a given 2-year study period. If individuals had more than one test during that period, we used results from the most recent (last) test, reasoning that later tests were more likely to be accurate. Study periods were based on 9/11 years. For example, the first post-9/11 period included bloods drawn from 9/11/2001 to 9/10/2003. An individual was represented only once in a specific time period, although he could have appeared in multiple periods. All individuals who had an anti-HCV test result during that time period comprised the denominator while anti-HCV positive individuals comprised the numerator for the serial, cross-sectional prevalence rates (Figure 2). For this analysis, liver function tests were not used to presume a negative anti-HCV result.

2.4 | Statistical analysis

We used descriptive statistics, specifically chi-squared analyses to assess the significance of differences in anti-HCV incidence during two time periods and t-tests for differences in continuous variables, like mean ages. Similarly, trends in prevalence over time were assessed using the Cochrane-Armitage test for trend. Since age-adjusted prevalence rates for men were available from the New York City Health and Nutrition Examination Survey (NYC HANES) for 2004[23] and 2014,[24] we age-adjusted FDNY rates for similar years (2004 and 2012) to the same Year 2000 US standard population as was done for the NYC HANES comparison study by Bornschlagel et al.[23] All statistical tests were 2-tailed; statistical significance was achieved at $P < 0.05$. Statistical analyses were performed using SAS software (SAS Institute Inc., NC; Version 9.4).

3 | RESULTS

On 9/11, the mean ages of firefighters and EMS were 40 years and 37 years, respectively, most cohort members were white (93.4% of firefighters and 52.5% of EMS). Many workers reported handling body parts during their work at the WTC site (34% of the total cohort and 40% of those who were anti-HCV positive). Table 1 shows the characteristics of the WTC-exposed prevalence cohort, and of those whose final routine screening test was anti-HCV positive ($n = 151$); it also includes characteristics of the subgroup who met requirements for the incidence study ($n = 2867$) and of the 17 who seroconverted during either the trans-9/11 or post-9/11 study periods. The incidence cohort was similar to the prevalence cohort in most characteristics, except that a greater proportion (58%) of the total incidence cohort reported handling body parts compared with 34% of the prevalence cohort ($P < 0.0001$).

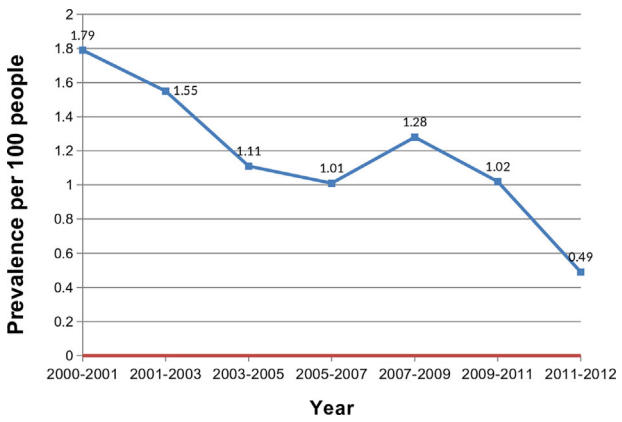

FIGURE 2 Prevalence of antibody to hepatitis C virus (Anti-HCV) positivity in Fire Department of the city of New York (FDNY) World Trade Center (WTC)-exposed male workers in 2-year periods: (2000-2001) 43/2404; (2001-2003) 150/9685; (2003-2005) 59/5304; (2005-2007) 45/4456; (2007-2009) 120/9342; (2009-2011) 78/7650; (2011-2012) 24/4915 [Color figure can be viewed at wileyonlinelibrary.com]

The incidence of anti-HCV seroconversion was 0.42 per 100 persons in the trans-9/11 period (12 of 2867; nine firefighters and three EMS) (Figure 1A), compared with 0.34 per 100 persons in the post-9/11 period (5 of 1491; four firefighters and one EMS) (Figure 1B), rates which are not statistically different ($P = 0.67$). EMS comprised 23% of the incidence population ($n = 660$ of 2867) and 24% ($n = 4$) of the seroconverters. This was similar to the firefighter proportion where firefighters comprised 77% of the incidence population ($n = 2207$ of 2867) and 76% ($n = 13$) of the seroconverters.

The prevalence study was based on 43 808 blood specimens for anti-HCV drawn from the population of 10 047 WTC-exposed male firefighters and 1,327 WTC-exposed EMS from 1/14/2000 to 12/31/2012. The overall prevalence of anti-HCV positivity at the time of each worker's last anti-HCV test was 151/11 374 (1.3%) (Figure 1C). By work assignment on 9/11, the seroprevalence rate among EMS at the time of their last test was almost double that of firefighters: 2.1% versus 1.2% ($P = 0.01$). We note, however, that pre-9/11 EMS had a higher prevalence at the time of their first anti-HCV test: 2.9% in EMS vs 1.9% in firefighters. The age-specific prevalence was highest in those aged 50-59 (4.6%) and lowest in those 18-29 (0%), although the prevalence was also 1% among the small group of men older than 60 on 9/11 ($n = 95$). Despite a significant increase in mean age over time, ($P < 0.0001$), secular trends showed that the prevalence of anti-HCV declined from 1.79 per 100 in the pre-9/11 period (2000-2001) to 0.49 per 100 in the final period, 2011-2012 (P test for trend $P < 0.0001$) (Figure 2).

To directly compare FDNY prevalence to NYC HANES rates in men, we age-adjusted the FDNY prevalence during 2004 and 2012, as was done for NYC HANES rates during 2004 and 2014. In 2004, the NYC HANES rate for men was 2.7% (1.6-4.6) whereas for FDNY men the rate was was lower, but not significantly so 1.6% (1.1-2.1). Similarly, in 2014, the NYC HANES rate for men was 1.3% (0.6-2.7)[24] whereas the FDNY rate was slightly, but not significantly, lower at 1.1% (0.5-1.6).

We identified 214 men with a positive screening test during the study period, among whom 189 had at least one available confirmatory test result. Of this group, 156 (82.5%) were confirmed positive. Applying this rate, we estimate that 125 of the 151 who were positive at their last screening test were likely infected. Most (92%) positive screening tests lacking confirmation were from 2007 or earlier, before confirmatory testing was consistently performed.

TABLE 1 Characteristics of World Trade Center (WTC)-exposed male responders with routine antibody to hepatitis C virus (Anti-HCV) test results from 2000 to 2012

	Prevalence population[a]	Prevalence HCV positive	Incidence population[b]	Incidence HCV positive
	Total (*N* = 11 374)	% positive (*N* = 151)	Total (*N* = 2867)	% positive (*N* = 17)
Current class				
Firefighter	10 047 (88%)	123 (81%)	2207 (77%)	13 (76%)
EMS	1327 (12%)	28 (19%)	660 (23%)	4 (24%)
Race/ethnicity				
White	10 077 (89%)	115 (76%)	2411 (84%)	15 (88%)
Hispanic	682 (6%)	15 (10%)	233 (8%)	1 (6%)
African American	546 (5%)	21 (14%)	196 (7%)	1 (6%)
Asian	60 (1%)	0	25 (1%)	0
Native American	9 (0%)	0	2 (0%)	0
Exposure				
1	1901 (17%)	31 (21%)	499 (17%)	3 (18%)
2	5732 (50%)	66 (44%)	1345 (47%)	8 (47%)
3	1916 (17%)	26 (17%)	479 (17%)	3 (18%)
4	1604 (14%)	24 (16%)	463 (16%)	3 (18%)
5	221 (2%)	4 (3%)	81 (3%)	0
Retirement status on last test				
Active	7819 (69%)	76 (50%)	2022 (71%)	9 (53%)
Retired	3555 (31%)	75 (50%)	845 (29%)	8 (47%)
Age on 9/11				
18-29	947 (8%)	0	328 (11%)	1 (6%)
30-39	4561 (40%)	12 (8%)	1122 (39%)	5 (29%)
40-49	4578 (40%)	84 (56%)	1106 (39%)	8 (47%)
50-59	1193 (11%)	55 (36%)	290 (10%)	3 (18%)
Over 60	95 (1%)	0	21 (1%)	0
Total number of months worked for at least 1 day at WTC site				
1	3300 (29%)	69 (46%)	923 (32%)	6 (35%)
2	1746 (15%)	23 (15%)	424 (15%)	2 (12%)
3	1502 (13%)	12 (8%)	359 (13%)	3 (18%)
4	1121 (10%)	7 (5%)	274 (10%)	1 (6%)
5	974 (9%)	10 (7%)	251 (9%)	3 (18%)
6	789 (7%)	8 (5%)	179 (6%)	0
7	615 (5%)	6 (4%)	124 (4%)	1 (6%)
8	345 (3%)	4 (3%)	83 (3%)	0
9	314 (3%)	6 (4%)	75 (3%)	0
10	668 (6%)	6 (4%)	175 (6%)	1 (6%)
Handle body part				
Yes	3917 (34%)	60 (40%)	1677 (58%)	12 (71%)
No	6777 (60%)	81 (54%)	1031 (36%)	5 (29%)
Missing	680 (6%)	10 (7%)	159 (6%)	0

9/11, September 11, 2001; EMS, Emergency Medical Services worker; HCV, Hepatitis C Virus.

[a]WTC-exposed male firefighters and EMS workers who came to FDNY for medical monitoring between 1/14/2000 and 12/31/2012 and had routine blood tests performed as part of their visit.

[b]Incidence population consisted of a trans-9/11 group (*n* = 2867), a subset of which comprised the post-9/11 group (*n* = 1491).

4 | DISCUSSION

The goals of this study were to assess the impact of work as a first responder at the WTC site in relation to the incidence of new, post-9/11 anti-HCV seroconversion and to estimate the secular trends in anti-HCV seroprevalence in FDNY male responders. In total, we identified 12 individuals who seroconverted during the trans-9/11 period (0.42%) from the group of 2867 WTC-exposed workers who had the requisite anti-HCV or liver function tests ("low or normal") and thus were likely anti-HCV-negative pre-9/11. In the subsequent post-9/11 period, 5 others seroconverted from the group of 1491 WTC-exposed workers who were anti-HCV-negative at their first post-9/11 test (0.34%). These seroconversion rates demonstrate similarity between the trans-9/11 and post-9/11 periods. Importantly, we did not see a meaningful difference in seroconversion rates between EMS and firefighters, as the proportion of seroconverters in each group was commensurate with their numbers in the incidence cohort. These seroconversion rates are consistent with the results of our serial, cross sectional analyses, which showed statistically significant declines in anti-HCV antibody prevalence over time.

In our prevalence study, we saw rates that declined from 1.79% pre-9/11 to 0.49% in 2011-2012, in almost perfect step-wise fashion, despite an uptick during 2007-2008, which corresponded with an increase in the mean age of participants due to our successful outreach to retirees (mean age 2003-2005 was 40.9 vs mean age 2007-2009 was 46.9 years, $P < 0.0001$). In most studies, including our own, older age, specifically being born from 1945 to 1965, has been shown to be a risk factor for HCV positivity.[25] Other known risk factors in the general population include male sex, geographic location, occupation, blood transfusions prior to routine screening for HCV in 1992, adult incarceration and especially, current or former injection drug use.

Differences in prevalence by sex have been reported nationally and locally, usually showing higher rates in males.[18] In 2004, adjusted overall estimates in males for National Health and Nutrition Examination Survey (NHANES) estimates were reported as 2.1% (1.4-3.2),[26] while NYC HANES were 2.7% (1.6-4.6),[23] rates which are not significantly different, but may reflect a somewhat larger number of NYC residents from high-risk population groups.[23] In the last 5 years (2012-2017), geographic differences have become more pronounced, commensurate with a surge in injection opioid use.[27] Early investigations of newly acquired HCV infections reveal that most occur among young, white persons living in non-urban areas.[28]

Some occupations, especially ones where individuals come into contact with large amounts or repeated direct percutaneous blood exposures, have been suggested as placing workers at higher than average risk. One meta-analysis of anti-HCV prevalence in healthcare workers found significantly elevated rates that were approximately double those in the general population,[29] although a more recent study at one site reported very low rates of seroconversion after documented contact with infected patients.[7] Our data show low anti-HCV positive rates at FDNY, although within the cohort, EMS prevalence rates were nearly double rates in firefighters. However, since this discrepancy was present pre-9/11, and our incidence study suggested that EMS were not more likely to seroconvert in either the trans-9/11 or post-9/11 period, we are confident that WTC exposure could not have played an important role in the disparity.

We believe that seroconversion rates, both trans- and post-9/11, and our seroprevalence rates at all time points were low for several reasons. First, the bodies and body parts of injured and deceased at the WTC site were not likely to have been infected, that is, that the 9/11 victims represented a low risk group of mostly young, working adults. In addition, in the event that contact was established with an infected body part, the virus has an unknown ability to withstand the high temperatures generated during the WTC-related fires. Second, during most of the rescue and recovery operation, FDNY personnel wore gloves and other personal protective equipment that served as an effective barrier. Third, FDNY firefighters and EMS are screened pre-hire for illicit drug use and are tested post-hire, both randomly, and for cause, which likely ensured that they had low personal risk of anti-HCV positivity.

Study limitations include that pre-9/11, anti-HCV results were missing for many individuals, resulting in our use of "low" or "normal" liver function test levels in lieu of negative anti-HCV test results in the trans-9/11 incidence study, which may have been a suboptimal measure of anti-HCV. However, we obtained similar results, albeit with less statistical power, when we limited our analyses to only those with documented pre-9/11 anti-HCV results. Second, confirmatory results from anti-HCV positive specimens were not always available. However, based on existing results, we were able to estimate the chronic infection rate as 82.5% of those with seropositive anti-HCV, a proportion that is consistent with the 80% reported by NHANES 1999-2002 rates[30] and previously used in estimating chronic infection in NYC.[23] Third, FDNY discontinued routine monitoring of anti-HCV seroprevalence in 2012. Since city-wide rates declined during the study period, FDNY rates would likely have further declined over the last 3 years. In fact, this is why the decision was made to discontinue routine surveillance in the absence of a documented exposure. Finally, our WTC-exposed cohort is not representative of all NYC residents as we included only males, 89% of whom were white, and all of whom are or were "healthy workers" and therefore at lower risk of HCV infection. Unfortunately, we had too few women to estimate stable incidence and prevalence rates. Study strengths include a large sample of over 11 000 routinely screened men enrolled in the FDNY cohort prior to 9/11 and who worked for a mean of 3.7 months at the WTC site.

In conclusion, we found that work at the WTC site was not associated with anti-HCV seroconversion in the FDNY population: neither firefighters nor EMS had an elevated seroconversion rate in the trans-9/11 period compared to the post-9/11 rate, or an elevated prevalence of HCV positivity compared with local NYC populations. However, further research should include an exploration of the observed disparity in HCV infection rates between EMS and firefighters. This study serves as confirmation of the current FDNY practice that provides anti- HCV testing for new employees and testing by indication of exposure for active employees as the most reasonable course.

AUTHORS' CONTRIBUTION

MPW is the principal investigator and contributed in study design and wrote the first draft of the manuscript. She is responsible for the integrity of all aspects of this work. YL is a Biostatistician, responsible for data cleaning, SAS programming, and preliminary and final analyses. HWC contributed in analytic and study design consultation, manuscript editing. TS contributed in supervising biostatistician, is responsible for SAS code checking, data validation, and manuscript editing. MDW contributed in analytic and study design consultation, clinical consultation, and manuscript editing. KK contributed in clinical consultation and manuscript editing. VO contributed in clinical consultation and manuscript editing. RZO contributed in project supervision and analytic design. NJ contributed in confirmation of Hep-C results and manuscript editing. HLC contributed in SAS code checking and manuscript editing. DJP contributed in intellectual leadership, manuscript editing, and is responsible for the integrity of all aspects of this work.

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ETHICS APPROVAL AND INFORMED CONSENT

The Albert Einstein College of Medicine/Montefiore Medical Center Institutional Review Board reviewed and approved this study. Data was used from participants who provided written consent.

DISCLOSURE (AUTHORS)

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Steven B. Markowitz declares that he has no conflict of interest in the review and publication decision regarding this article.

DISCLAIMER

The FDNY had no role in study design; collection, analysis, and/or interpretation of data; writing the report; and the decision to submit the report for publication.

ORCID

Mayris P. Webber http://orcid.org/0000-0002-8322-4573

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