

# Estimation of Future Cancer Burden Among Rescue and Recovery Workers Exposed to the World Trade Center Disaster

Ankura Singh, MPH; Rachel Zeig-Owens, DrPH; William Moir, MPH; Charles B. Hall, PhD; Theresa Schwartz, MS; Madeline Vossbrinck, MS; Nadia Jaber, PA-C; Mayris P. Webber, DrPH; Kerry J. Kelly, MD; Viola Ortiz, MD; Ellen Koffler, MD; David J. Prezant, MD

**IMPORTANCE** Elevated rates of cancer have been reported in individuals exposed to the World Trade Center (WTC) disaster, including Fire Department of the City of New York (FDNY) rescue and recovery workers.

**OBJECTIVE** To project the future burden of cancer in WTC-exposed FDNY rescue and recovery workers by estimating the 20-year cancer incidence.

**DESIGN, SETTING, AND PARTICIPANTS** A total of 14 474 WTC-exposed FDNY employees who were cancer-free on January 1, 2012; subgroup analyses were conducted of the cohort's white male population (n = 12 374). In this closed-cohort study, we projected cancer incidence for the January 1, 2012, to December 31, 2031, period. Simulations were run using demographic-specific New York City (NYC) cancer and national mortality rates for each individual, summed for the whole cohort, and performed 1000 times to produce mean estimates. Additional analyses in the subgroup of white men compared case counts produced by using 2007-2011 FDNY WTC Health Program (FDNY-WTCHP) cancer rates vs NYC rates. Average and 20-year aggregate costs of first-year cancer care were estimated using claims data.

**EXPOSURES** World Trade Center disaster exposure defined as rescue and recovery work at the WTC site at any time from September 11, 2001, to July 25, 2002.

**MAIN OUTCOMES AND MEASURES** (1) Projected number of incident cancers in the full cohort, based on NYC cancer rates; (2) cancer incidence estimates in the subgroup projected using FDNY-WTCHP vs NYC rates; and (3) estimated first-year treatment costs of incident cancers.

**RESULTS** On January 1, 2012, the cohort was 96.8% male, 87.1% white, and had a mean (SD) age of 50.2 (9.2) years. The projected number of incident cancer cases was 2960 (95% CI, 2883-3037). In our subgroup analyses using FDNY-WTCHP vs NYC cancer rates, the projected number of new cases in white men was elevated (2714 [95% CI, 2638-2786] vs 2596 [95% CI, 2524-2668]). Accordingly, we expect more prostate (1437 [95% CI, 1383-1495] vs 863 [95% CI, 816-910]), thyroid (73 [95% CI, 60-86] vs 57 [95% CI, 44-69]), and melanoma cases (201 [95% CI, 179-223] vs 131 [95% CI, 112-150]), but fewer lung (237 [95% CI, 212-262] vs 373 [95% CI, 343-405]), colorectal (172 [95% CI, 152-191] vs 267 [95% CI, 241-292]), and kidney cancers (66 [95% CI, 54-80] vs 132 [95% CI, 114-152]) ( $P < .001$  for all comparisons). The estimated 20-year cost of first-year treatment was \$235 835 412 (95% CI, \$187 582 227-\$284 088 597).

**CONCLUSIONS AND RELEVANCE** We project that the FDNY-WTCHP cohort will experience a greater cancer burden than would be expected from a demographically similar population. This underscores the importance of cancer prevention efforts and routine screening in WTC-exposed rescue and recovery workers.

JAMA Oncol. 2018;4(6):828-831. doi:10.1001/jamaoncol.2018.0504  
Published online April 26, 2018.

← Editorial [page 775](#)

← Related article [page 821](#)

+ Supplemental content

**Author Affiliations:** Author affiliations are listed at the end of this article.

**Corresponding Author:** Rachel Zeig-Owens, DrPH, FDNY World Trade Center Health Program, 9 Metrotech Center SE-63-K, Brooklyn, NY 11201 ([rachel.zeig-owens@fdny.nyc.gov](mailto:rachel.zeig-owens@fdny.nyc.gov)).

Individuals involved in the rescue and recovery effort at the World Trade Center (WTC) disaster site on and after September 11, 2001 were likely exposed to multiple carcinogenic agents because the WTC dust cloud contained known and potential carcinogens, including asbestos, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and dioxins.<sup>1,2</sup> Previously, we and others reported modestly elevated rates of cancer in WTC-exposed rescue and recovery workers compared with general populations.<sup>3-6</sup>

The purpose of this investigation was to project the cohort's future cancer burden by estimating the 20-year incidence of cancer, using both New York City (NYC) cancer rates (modeling impact of aging) and Fire Department of the City of New York WTC Health Program (FDNY-WTCHP) rates (modeling the additional impact of exposure) from the most recent 5-year period for which we had complete cancer data (2007-2011). We then used the projected case counts and first-year medical costs of recently diagnosed cases to develop an approximation of anticipated FDNY-WTCHP spending on initial phase cancer treatment. These estimates of disease burden should inform policy decisions because they offer insights into future needs for monitoring and treatment of WTC-exposed populations.

## Methods

### Study Population

The FDNY-WTCHP includes 15 507 rescue and recovery workers. The study population was limited to the 14 474 who were alive and free of cancer as of January 1, 2012. The Montefiore Medical Center and Albert Einstein College of Medicine institutional review board approved this study and waived informed consent. We conducted data analyses starting in March 2016 and completed all analyses by July 2017.

### Cancer Rates and Claims Data

We obtained age-, race- and sex-specific NYC cancer rates for the 2007-2011 period from the New York State Cancer Registry. FDNY-WTCHP cancer rates in the white male subpopulation ( $n = 12\,374$ ) were calculated using 2007-2011 FDNY-WTCHP cancer data (includes confirmed cases and state registry matches). We also calculated a second set of FDNY-WTCHP cancer rates for white men that were adjusted for potential surveillance bias, delaying the diagnosis dates of certain cancers by 2 years. Current cancer incidence costs in the FDNY-WTCHP were calculated using the medical claims data of recently diagnosed participants ( $n = 169$ ).

### Statistical Analyses

We used NYC cancer rates and US death rates (obtained from the National Center for Health Statistics<sup>7</sup>) in simulations to estimate overall and site-specific cancer incidence in the WTC-exposed FDNY population from January 1, 2012, to December 31, 2031.

To examine if the calculated FDNY-WTCHP cancer rates would produce different results, we restricted the population to white men and performed the simulations first using NYC

## Key Points

**Question** What is the estimated number of new cancer cases among rescue and recovery workers exposed to carcinogenic agents during the September 11, 2001, World Trade Center (WTC) attack for the January 1, 2012, to December 31, 2031, period?

**Findings** An estimated 2960 new cancer cases in the WTC-exposed cohort ( $n = 14\,474$ ) may occur during this 20-year period. Analyses restricted to white male workers showed greater cancer incidence than would be expected based on NYC rates for this demographic group, corresponding to a significantly elevated number of projected cases (2714 vs 2596).

**Meaning** The future cancer burden in WTC-exposed rescue and recovery workers may be greater than expected based on a demographically similar population.

rates and then FDNY-WTCHP rates. We then reran this analysis with FDNY-WTCHP rates that were adjusted for possible surveillance bias.

Finally, using the 20-year case counts projected from our primary analysis and the estimated per-patient costs of first-year cancer care, we created aggregate estimates of the direct medical costs of initial care from January 1, 2012, to December 31, 2031. Data analyses were performed using SAS statistical software (version 9.4; SAS Institute Inc) and Microsoft Excel software. We used  $t$  tests to compare mean case counts. Two-sided  $P < .05$  was considered significant. See the [Supplement](#) for a detailed eMethods section.

## Results

### FDNY-WTCHP Population and Cancer Diagnoses

The cohort was 96.8% male and 87.1% white, and the mean (SD) age was 50.2 (9.2) years. Selected demographic characteristics of the cohort as of January 1, 2012 ( $n = 14\,474$ ), and the white male subgroup ( $n = 12\,374$ ) are displayed in eTable 1 in the [Supplement](#). The [Table](#) displays the number of confirmed primary cancer cases diagnosed from September 11, 2001, to December 31, 2011 ( $n = 697$ ).

### Estimated 20-Year Cancer Incidence

Based on 2007-2011 NYC rates, the expected number of incident first primary cancer cases from January 1, 2012, to December 31, 2031, is 2960 (95% CI, 2883-3037) (Table). The increasing incidence (95% CI) seen in each 5-year interval over follow-up is due to aging of the population: 2012 to 2016, 560 (95% CI, 524-597); 2017 to 2021, 703 (95% CI, 663-749); 2022 to 2026, 822 (95% CI, 776-869); and 2027 to 2031, 873 (95% CI, 826-919).

The FDNY-WTCHP cancer rates projected a modestly higher number of cases in the white male subgroup than did NYC rates (2714 [95% CI, 2638-2786] vs 2596 [95% CI, 2524-2668];  $P < .001$ ). Specifically, higher projected case counts of prostate cancer, thyroid cancer, and melanoma were observed when FDNY-WTCHP rates were used (1437 [95% CI, 1382-1495] vs 863 [95% CI, 816-910], 73 [95% CI, 60-86] vs 57

Table. Number of Known and Estimated First Primary Cancer Cases in FDNY WTC-Exposed Cohort

Cancer Site	Known Cases, Sept 11, 2001-Dec 31, 2011, No.	Mean (SD)		Projected Cases, Jan 1, 2012-Dec 31, 2031, No. (95% CI)
		Age at Diagnosis, Sept 11, 2001-Dec 31, 2011, y	Years to Diagnosis, Sept 11, 2001-Dec 31, 2011	
Any	697	55.81 (9.62)	6.18 (2.85)	2960 (2883-3037)
Prostate	290	58.89 (7.64)	6.48 (2.71)	995 (946-1050)
Lung	31	63.11 (6.75)	6.72 (2.81)	416 (383-450)
Hematologic <sup>a</sup>	79	53.93 (9.89)	6.12 (2.96)	313 (286-341)
Colorectal	48	54.35 (8.01)	5.29 (2.97)	305 (278-331)
Melanoma	69	52.30 (10.38)	5.99 (2.88)	133 (114-152)
Bladder	37	57.82 (11.10)	6.53 (3.10)	230 (206-252)
Kidney	30	52.47 (8.70)	5.45 (2.97)	145 (125-165)
Thyroid	37	45.88 (9.34)	5.98 (2.81)	63 (50-76)

Abbreviations: FDNY, Fire Department of the City of New York; WTC, World Trade Center.

<sup>a</sup> Includes Hodgkin lymphoma, non-Hodgkin lymphoma, leukemia, multiple myeloma, and other hematopoietic cancers.

[95% CI, 44-69], and 201 [95% CI, 179-223] vs 131 [95% CI, 112-150], respectively;  $P < .001$  for all comparisons) (eFigure 1A in the Supplement). Conversely, FDNY-WTCHP rates produced significantly lower estimates of other site-specific cancers (eResults, eFigure 1A in the Supplement).

Results from the sensitivity analysis, with FDNY-WTCHP rates adjusted for possible surveillance bias, showed no significant difference between the future case counts of all cancers combined in white men as estimated by FDNY and NYC rates (2560 [95% CI, 2480-2633] vs 2596 [95% CI, 2524-2668];  $P = .68$ ). The projected number of prostate cancers, however, remained significantly higher than the NYC rate-derived estimate (1271 [95% CI, 1213-1324] vs 863 [95% CI, 816-910];  $P < .001$ ) (eFigure 1B in the Supplement).

### Financial Burden

Using FDNY-WTCHP mean cancer care cost estimates (eTable 2 in the Supplement), the projected aggregate 20-year initial phase medical cost of incident cancers (all-sites) is approximately \$235 835 412 (95% CI, \$187 582 227-\$284 088 597) (in 2015 dollars).

## Discussion

Our findings suggest that the FDNY WTC-exposed cohort may experience a greater burden of cancer than would be expected from a population with similar demographic characteristics. The elevated incidence of prostate cancer, thyroid cancer, and melanoma that was observed using FDNY-WTCHP cancer rates is consistent with findings from other cancer studies of WTC-exposed individuals.<sup>3-6</sup> After FDNY-WTCHP rates for prostate and thyroid cancer were adjusted to partially account for surveillance bias, the resulting cancer counts remained significantly higher than those estimated from NYC rates. Those who performed work at the WTC site may be at increased risk for prostate cancer, thyroid cancer, and melanoma owing to their exposure to carcinogens in the WTC dust.<sup>1,2,8-11</sup> Alternatively, FDNY-WTCHP rates may be elevated owing to insufficient surveillance bias adjustments.

### Strengths and Limitations

The projected cancer counts that were produced using FDNY-WTCHP white male rates were based on actual cancers diag-

nosed from 2007 to 2011. Follow-up time was likely inadequate for the development of WTC-exposure-related cases of some cancer subtypes with long latency periods. For example, lung cancer latency among asbestos-exposed workers has been shown to be 25 to 40 years,<sup>12</sup> and so we expect few WTC-exposure-related lung cancers to be included in the 2007-2011 rates. Conversely, FDNY rates may overestimate the future incidence of cancers with shorter latency periods, such as thyroid and certain hematologic cancers.<sup>13</sup> One limitation specific to the cost analysis was that the use of annual case counts projected by NYC rates instead of FDNY-WTCHP rates meant that we likely overestimated future spending on lung cancer and underestimated that of prostate. In addition, the cost analysis did not examine cancer care that took place more than 12 months after diagnosis, such as distant treatment, surveillance, and end-of-life care.

Our cohort may not be fully generalizable to the general WTC-exposed population. It is possible that firefighters have a higher risk of cancer than the general population owing to exposures associated with the occupation.<sup>14</sup> Alternatively, FDNY rescue and recovery workers were a healthy occupational cohort at the time of the WTC disaster, differing from the general population on some characteristics, such as having a lower smoking rate.<sup>15</sup> This may explain the comparatively low FDNY-WTCHP rates of certain cancers, like lung cancer, and may therefore underestimate future cancer incidence and costs.

Study strengths include a cohort defined prior to WTC exposure, thereby minimizing enrollment bias; use of 2007-2011 FDNY-WTCHP cancer rates, which exclude prevalent cancers diagnosed shortly after September 11, 2001; and nearly complete matching with tumor registries, minimizing loss to follow-up. Finally, we addressed potential surveillance bias by performing a sensitivity analysis using adjusted FDNY-WTCHP cancer rates.

## Conclusions

The projected case counts and costs provide insight into future utilization of cancer resources. Given the elevated incidence of some cancer subtypes observed in this and other WTC-exposed cohorts, it is imperative that WTC-exposed cohorts continue to

undergo cancer prevention efforts and screening to reduce this burden and allow for early detection. Patients with cancer, meanwhile, will need access to various treatments. The WTCHP must budget for appropriate resources, given the anticipated increase in cancer incidence, including preventive care, diagnosis, treat-

ment, and cancer-related palliative and end-of-life care. We also advocate for establishing policies to protect the health of workers responding to similar disasters, such as mandating the use of appropriate protective equipment and limiting the amount of time workers can spend at disaster sites.

## ARTICLE INFORMATION

**Accepted for Publication:** December 15, 2017.

**Published Online:** April 26, 2018.

doi:10.1001/jamaoncol.2018.0504

**Author Affiliations:** Pulmonary Medicine Division, Department of Medicine, Montefiore Medical Center and Albert Einstein College of Medicine, Bronx, New York (Singh, Zeig-Owens, Moir, Schwartz, Vossbrinck, Prezant); The Bureau of Health Services and Office of Medical Affairs, Fire Department of the City of New York, Brooklyn, New York (Singh, Zeig-Owens, Moir, Schwartz, Vossbrinck, Jaber, Webber, Kelly, Ortiz, Koffler, Prezant); Division of Epidemiology, Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, New York (Zeig-Owens, Webber); Division of Biostatistics, Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, New York (Hall).

**Author Contributions:** Drs Zeig-Owens and Prezant had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

*Study concept and design:* Zeig-Owens, Moir, Hall, Webber, Prezant.

*Acquisition, analysis, or interpretation of data:* Singh, Zeig-Owens, Moir, Schwartz, Vossbrinck, Jaber, Kelly, Ortiz, Koffler.

*Drafting of the manuscript:* Singh, Zeig-Owens, Webber.

*Critical revision of the manuscript for important intellectual content:* Zeig-Owens, Moir, Hall, Schwartz, Vossbrinck, Jaber, Kelly, Ortiz, Koffler, Prezant.

*Statistical analysis:* Singh, Zeig-Owens, Moir, Schwartz.

*Obtained funding:* Prezant.

*Administrative, technical, or material support:* Hall, Vossbrinck, Kelly, Ortiz, Koffler, Prezant.

*Study supervision:* Zeig-Owens, Hall, Webber, Prezant.

**Conflict of Interest Disclosures:** None reported.

**Funding/Support:** This research was supported by National Institute of Occupational Safety and Health (NIOSH) grant 1U01OH010728-01 and NIOSH contracts 200-2011-39383, 200-2011-39378, 200-2017-93326, and 200-2017-93426.

**Role of the Funder/Sponsor:** The sponsor had no role in the design and conduct of the study, the collection, management, analysis, and interpretation of the data, the preparation, review, and approval of the manuscript, or the decision to submit the manuscript for publication.

## REFERENCES

- Landrigan PJ, Lioy PJ, Thurston G, et al; NIEHS World Trade Center Working Group. Health and environmental consequences of the world trade center disaster. *Environ Health Perspect*. 2004;112(6):731-739.
- Lioy PJ, Weisel CP, Millette JR, et al. Characterization of the dust/smoke aerosol that settled east of the World Trade Center (WTC) in lower Manhattan after the collapse of the WTC 11 September 2001. *Environ Health Perspect*. 2002;110(7):703-714.
- Zeig-Owens R, Webber MP, Hall CB, et al. Early assessment of cancer outcomes in New York City firefighters after the 9/11 attacks: an observational cohort study. *Lancet*. 2011;378(9794):898-905.
- Solan S, Wallenstein S, Shapiro M, et al. Cancer incidence in world trade center rescue and recovery workers, 2001-2008. *Environ Health Perspect*. 2013;121(6):699-704.
- Li J, Cone JE, Kahn AR, et al. Association between World Trade Center exposure and excess cancer risk. *JAMA*. 2012;308(23):2479-2488.
- Li J, Brackbill RM, Liao TS, et al. Ten-year cancer incidence in rescue/recovery workers and civilians exposed to the September 11, 2001 terrorist attacks on the World Trade Center. *Am J Ind Med*. 2016;59(9):709-721.
- Kochanek KD, Murphy SL, Xu J. Deaths: final data for 2011. *Natl Vital Stat Rep*. 2015;63(3):1-120.
- Gallagher RP, Macarthur AC, Lee TK, et al. Plasma levels of polychlorinated biphenyls and risk of cutaneous malignant melanoma: a preliminary study. *Int J Cancer*. 2011;128(8):1872-1880.
- Hagmar L. Polychlorinated biphenyls and thyroid status in humans: a review. *Thyroid*. 2003;13(11):1021-1028.
- Boffetta P, Jourenkova N, Gustavsson P. Cancer risk from occupational and environmental exposure to polycyclic aromatic hydrocarbons. *Cancer Causes Control*. 1997;8(3):444-472.
- Ruder AM, Hein MJ, Hopf NB, Waters MA. Mortality among 24,865 workers exposed to polychlorinated biphenyls (PCBs) in three electrical capacitor manufacturing plants: a ten-year update. *Int J Hyg Environ Health*. 2014;217(2-3):176-187.
- Selikoff IJ, Hammond EC, Seidman H. Latency of asbestos disease among insulation workers in the United States and Canada. *Cancer*. 1980;46(12):2736-2740.
- Breslow NE, Day NE. Statistical Methods in Cancer Research: Volume I: The Analysis of Case-Control Studies. IARC Sci Publ. Lyon, France: IARC; 1993. <https://www.iarc.fr/en/publications/pdfs-online/stat/sp32/SP32.pdf>. Accessed February 19, 2018.
- Daniels RD, Kubale TL, Yiin JH, et al. Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950-2009). *Occup Environ Med*. 2014;71(6):388-397.
- New York City Department of Health and Mental Hygiene. Epiquery: NYC Interactive Health Data System—Community Health Survey, 2015. Accessed August 10, 2017. <https://nyc.gov/health/epiquery>. Accessed February 21, 2018.