WORLD TRADE CENTER
RESPONDERS FATALITY INVESTIGATION PROGRAM

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Background

The World Trade Center (WTC) disaster on September 11, 2001 led to a response by a variety of workers. Workers and volunteers were involved in virtually every aspect of the response, including rescue and recovery, security, traffic control, demolition and assessing a range of health and safety parameters. These workers had variable levels of potential exposure dependent upon job tasks, time of first response, length of deployment, personal protective equipment use, and work locations. Although the responder cohorts with the greatest potential for high exposures included members of the Fire Department of New York (FDNY)[1], the New York Police Department (NYPD)[2] and construction workers, many other responders also had unmeasured exposures which could result in adverse health outcomes.

The collapse of the twin towers of the WTC resulted in a massive cloud of dust and debris that spread over a large area of lower Manhattan, as well as fires which burned out of control for many weeks. The content and distribution of material in the resulting plume was of a complex mixture of building debris and combustion. The dust has been characterized as caustic and alkaline[3,4]. Potential contaminants of exposure for workers included construction materials such as gypsum, calcite, and cement or concrete dust as well as metals, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins, polychlorinated dibenzofurans, glass fibers, and asbestos[5-8]. Recovery activities also resulted in potential exposures to diesel exhaust from construction equipment, trucks, and other sources.

Studies have demonstrated a number of health effects and symptoms in WTC response workers. These include WTC cough, exertional dyspnea, airway hyperreactivity, upper and lower respiratory symptoms, gastro-esophageal reflux symptoms, and sarcoidosis[9-17]. Psychological symptoms including depression and post-traumatic stress disorder were also reported in workers[18-20]. Although there is significant science-based literature on illnesses associated with WTC exposures, the same cannot be said of fatalities. To date, reports of WTC-related responder fatalities have been spurious and limited to news media reports and medical examiner/pathologist opinion. The WTC Responders Fatality Investigation (RFI) program was designed to be the data collection center for fatalities occurring among this population in order to conduct an initial assessment regarding whether responders are at a higher than normal risk for certain causes of death.

Methods

The study population included any death that occurred between September 12, 2001 and June 30, 2009 among responders to the WTC disaster between September 11, 2001 and June 30, 2002 including workers and volunteers at Ground Zero, the secure/exclusion zone, and the morgue or waste stream corridor including the Fresh Kills landfill in Staten Island. Because there was no central method to identify these responders, case ascertainment occurred through a variety of methods. Daily reviews were conducted of on-line newspapers in New Jersey, Connecticut, New York, and eastern Pennsylvania, and of national obituary search engines using key words such as “ground zero,” “WTC,” “World Trade Center” and “9/11.” Outreach and education was provided to over 200 groups about the project and the need to provide information on any WTC responder death. These included groups were involved with the medical monitoring, treatment or research of WTC responders, worker advocacy organizations, labor unions, and attorneys involved in lawsuits regarding WTC. Agreements were developed for data from FDNY, the WTC Health Registry, and the WTC Medical Monitoring and Treatment program to be shared with the WTC RFI program. A toll-free number and email account specific to this project was also established.

An attempt was made to collect a death certificate for every WTC responder, rescue worker and volunteer, who died since September 12, 2001 to confirm the death had occurred and to obtain causes of death. In states without public records, institutional review board approval was sought. A joint application was submitted to the National Death Index (NDI)[21] with the WTC Health Registry allowing for the sharing of NDI identified deaths.

Interviews with informed consent were conducted with the next-of-kin on all non-traumatic/non-suicide fatalities that occurred since January 1, 2006, when the project started. Interviews were not conducted for deaths prior to this date since many family members would have been completing their grieving process, and the researchers did not wish to upset family members. Interviews were not conducted with families of deaths due to trauma or suicides due to the sensitivity of these deaths. Confirmation of WTC exposure was obtained by contacting employers, and secondary sources such as unions, other employees, exposure questionnaires completed by the decedent prior to his/her death, and next-of-kin.

To better assess the health status of the decedents prior to their death, medical records from visits up to two years prior to September 11, 2001 were obtained. Information on where to access medical records was obtained from next-of-kin and from location of death identified on the death certificate, thus many records were not found for deaths that occurred outside of a hospital. Autopsy results including toxicologic results and medical examiners' notes were also obtained. Certain regions in the United States had restrictions on non-family members obtaining copies of autopsies.

Because there was no record of those individuals who responded to the WTC, a simulated cohort of 91,469 (the estimated number of responders from the WTC Health Registry[22]) was created using the "surveyselect" procedure in SAS 9.2 (SAS Institute Inc., Cary NC) with unrestricted random sampling. Ages, sex and start dates at WTC of the 30,665 responders from the WTC Health Registry were extrapolated to the full population while incorporating the identified deceased responders.

It was expected that the number of deaths identified would be less than the true number since the original cohort could not be identified. Therefore, two methods were used to estimate the expected number of deaths among the WTC responder population. The first method used capture-recapture estimation comparing four different sources of reports of fatalities (media, the WTC Health Registry, attorney reports, and all other reports combined)[23]. Log-linear modeling adjusting for dependencies between these groups was conducted[24]. A second method was developed using the generated random sample and applying the expected general US mortality rates.

Underlying cause of death was coded using ICD-10 codes[25] and was determined using the death certificate, medical records and autopsies. Cause-specific mortality was analyzed using proportionate mortality ratios (PMR) standardized for age and sex, using the following reference populations: US general population, the New York City (NYC) region which consists of 16 counties including and surrounding NYC where 61% of the identified deaths occurred (Bergen NJ, Bronx NY, Essex NJ, Hudson NJ, Kings NY, Middlesex NJ, Monmouth NJ, Nassau NY, New York NY, Orange NY, Queens NY, Richmond NY, Rockland NY, Suffolk NY, Union NJ, and Westchester NY), and NYC. These populations were created using CDC WONDER through 2006. In order to create a reference population for the same time period of the study, cause of death data were extrapolated for 2007-2009 using predicted values based on time-trends from 1999 through 2006. Standardized mortality ratios (SMRs) were conducted standardizing for age and sex using the same three reference populations. Numerators only included those individuals residing in those regions at the time of death. One of the methodologic problems associated with PMRs is the "seesaw" effect where if one or more causes of death are low, then other causes will automatically be high, even when there is no true risk[29]. In order to partially control for this seesaw effect, proportionate cancer mortality ratios (PCMRs) were also conducted.

The National Center for Health Statistics list of 113 selected causes of death was used for the general analysis of mortality[26]. Analyses were conducted only on those categories in which there were at least five deaths (n=42). *A priori* hypotheses based on high-risk morbidity among responder populations from the literature were developed and additional causes of death were included where necessary to allow for analyses of these hypotheses. These included cancers from colon, kidney and brain, non-Hodgkins lymphoma, and multiple myeloma; and cardiovascular diseases, specifically hypertensive disease, ischaemic heart disease and cerebrovascular disease. Mortality analyses were also conducted for deaths associated with high-risk behaviors that are potentially a response to psychological stress induced from exposures at WTC. This included deaths from external causes (both accidental and intentional) including all suicides, all homicides, accidental injuries (ICD10 codes V00- X59, Y85-Y86), intentional deaths, and from causes directly linked to alcohol or drugs[27,28].

Results

There were 836 deaths that met the criteria for inclusion in this project. An additional 34 individuals were subsequently excluded due to not working in the identified exposure zones. Death certificates were obtained for 786 deaths. Certificates could not be obtained for 50 individuals for the following reasons: unable to locate - 26; death occurred outside of the United States and no Foreign Service report of death was filed - 2; military deaths in Afghanistan and Iraq - 12; and deaths that occurred in states where human subjects approval could not be obtained or death certificates were not issued to researchers - 10. The cause of death was able to be confirmed for 29 of these 50 individuals through external sources including multiple media reports (primarily traumatic accidents or incidents of war), autopsies, NDI reports from the WTC Health Registry and/or medical records. Deaths were identified in 42 states with 38% occurring in NYC, 22% in the rest of NYS, 11% in New Jersey and 3% occurring outside of the United States.

The cause of death was confirmed for 814 deaths. Of the confirmed deaths, 291 met the interview criteria of which 49 (16.8%) were completed and 27 were refused (9.3%); there were 39 (13.4%) for whom next of kin was unable to be identified. The remaining families did not respond to multiple contact attempts, so they were treated as passive refusals. Seventy-nine percent (n=892) of the medical records requested were obtained; 90% (n=145) of the autopsy reports were received; and employment records related to WTC were obtained for 57% (n=219) of those requested.

Table 1 describes the demographics, year of death, the type of job worked in while at WTC, and the source of the first report for the confirmed responder deaths. Thirteen percent were female and 7% were Hispanic. The number of deaths identified increased each year to a high of 155 in 2007, and then decreased for 2008 through June 2009. The majority of deaths were identified through the media, either in obituaries or articles about the decedent. Another 28% were identified through the data sharing agreement with the WTC Health Registry, and an additional 18% were provided by attorneys. Few deaths were identified through contact by family, friends or unions. Among the deaths identified, 19% worked for governmental organizations primarily NYC and NYS agencies excluding the FDNY and NYPD, and for authorities such as the Metropolitan Transportation Authority and the Port Authority of New York and New Jersey. An equal number of fire and law enforcement personnel were identified, with 69% of the fire personnel working for FDNY and 67% of the law enforcement personnel working for NYPD.

The capture-recapture estimation provided an estimated number of deaths of 1,567 (resulting in ascertaining 53% of expected cases). Applying the expected general US mortality rates to the generated random sample using the age and sex distribution of the responder population from the WTC Health Registry resulted in an estimate of 3,135 deaths for a responder population of 91,469.

The SMRs are displayed in Table 2. Among the SMRs, no cause of death was statistically significantly elevated among all three comparison groups. The PCMRs are shown in Table 3. The only PCMRs that were elevated among all comparison groups were ovarian cancer and multiple myeloma and immunological cancers. These were examined further looking for patterns among those diagnosed regarding their demographic characteristics, age, and exposure characteristics. The five women diagnosed with ovarian cancer ranged in age from 47 to 61; three were White, one was of Hispanic origin, and one was African American. They died between 2004 and 2006; three were identified by the WTC Health Registry and they had a variety of employment at the WTC. The eight individuals diagnosed with multiple myeloma included 3 people diagnosed before 2005, one female, one of Hispanic origin, and they ranged in age at death from 35 to 83 with two individuals diagnosed younger than 45 years of age. Only two individuals were known to be caught in the cloud of dust, and there were no similarities in the dates worked at the site, the types of jobs worked, the length of time at the site, or their occupations. Of the two younger individuals, one was a police officer who worked at a building near the site for one day and the other was involved in health care delivery with unknown days and times in the WTC catchment area. The multiple myeloma deaths occurred from 2003 through 2009.

Limitations

Because there was no record of who responded to the WTC disaster, it is unknown how many responders were actually at the WTC site. The WTC Health Registry estimated the true eligible population of rescue/recovery and related workers to be 91,469[22]; other researchers have estimated that the number of responders was actually between 60,000 to 70,000[30]. To adjust for this difference, comparisons using the US general population were conducted reducing the size of the cohort to 65,000 but there was no significant difference in any of the results. In order to conduct SMR analyses, a random sample distribution based upon data from the WTC Health Registry was created to simulate a population of responders. However, comparisons of the demographics of deaths among the WTC Health Registry enrollees to all deaths has shown that these populations were significantly different, so the simulated denominator population may be inappropriate.

Incomplete death ascertainment can severely affect both the PMR and SMR analyses. The PMR is dependent on the number of deaths from other causes, so if the under ascertainment is not distributed uniformly across the various types of death, a bias will result. Analyses conducted to determine the extent of under ascertainment resulted in the identification of 27% (using the US General Population) to 47% (using capture-recapture analyses) of the deceased responders. Because there was such severe under ascertainment, the results of the PMR analyses were deemed unreliable. Likewise, under ascertainment also reduced the SMRs. The deaths identified may not be representative of all of the deaths that occurred among the responders due to the methods used to identify deaths. For example, deaths due to motor vehicle accidents were more likely to be identified through media reports, while deaths due to cancer were more likely to be identified from attorneys. Because 45% of the deaths were identified through media reports, it is suspected that deaths due to causes that were not expected to be associated with the WTC disaster, such as cardiovascular diseases would be less likely to be ascertained. Also, causes of death that may be associated with mental health issues may not be publicized through obituaries or newspaper accounts.

As the population that worked at WTC ages, the number of deaths occurring each year should increase. That the WTC RFI experienced a decrease in the number of deaths ascertained in 2008 and for half of 2009 is probably a result of the lack of NDI matches for that time period since death records through the NDI are available approximately two years after the end of a calendar year[22] and thus were not available for 2008 or 2009 at the close of this project. Also, as the time since the disaster increases, obituaries are less likely to report that the individual was a WTC responder.

Applying mortality rates from the general population is subject to biases resulting from the healthy worker effect. The healthy worker effect is a phenomenon where the mortality rates in a working population are lower than the general population. This is primarily due to the fact that the severely ill and disabled are usually excluded from being employed. This selection bias can continue to occur during employment in that those who are employed may have higher incomes and access to better healthcare than those not employed, thus keeping them healthier[31]; and that those who are less healthy are more likely to leave the active workforce. The healthy worker effect is also more apparent among those in physically demanding occupations or in occupations with specific physical fitness requirements in their hiring policies, such as many first responder occupations[32].

The choice of an inappropriate comparison population can contribute to the healthy worker effect. To partially control for this, mortality rates from three comparison populations were used. It was difficult to compare results across these populations due to the change in the number of deaths that occurred in each cause, and the low number of deaths for some of the comparisons may have contributed to rate instability. Because of the relatively small numbers, race was not adjusted for.

The potential for classification bias may exist because the underlying causes of death for the reference population were coded based on information only available from the death certificate while the causes of death for the responder population were more exact, using a combination of the death certificate, medical records and autopsy reports. A comparison was conducted of the cause of death codes for those deaths which were coded by either the NDI (n=136) or by the NYC Department of Health and Mental Hygiene (n=258). Agreement in the ICD10 code was achieved in 81% of the deaths as classified by the NDI and in 90% of the deaths as classified by the NYC Department of Health and Mental Hygiene indicating that this bias should not adversely affect any of the results. Disagreements between the various coding mechanisms were often a result of certificates being coded as “undetermined” when the cause of death was pending, and cases misclassified as suicides when they were accidents.

Discussion

The response to the WTC disaster was initially focused upon the rescue of individuals at the site. While there was prompt medical mobilization, the public health community began to recognize the need to assess long-term health consequences of the exposures to workers at the site a few months after the disaster occurred. Very soon after the disaster, researchers proposed establishing a registry of all workers and conducting baseline physical examinations of those at highest risk[33]. Since neither of these actions occurred, it is impossible both to identify the entire cohort at risk and to follow the health status of all exposed individuals over time; however, programs were established to assist in tracking illnesses related to the WTC disaster, including the WTC Health Registry and specialized medical monitoring and treatment services run through the WTC Centers of Excellence. Because these programs represented subsets of the entire exposed population, it was recognized that they could not immediately address whether the rescue workers were at higher risk for experiencing long-term health consequences or death from their exposures. In an attempt to gather information on a broader pool of individuals, the WTC RFI program was developed as a short-term response to assist in answering whether responders were potentially dying of specific causes from their exposures.

The PMR does not directly measure the risk of a person dying from a specific disease; it measures the difference in mortality from other causes of death. The PMR is useful in indicating the relative importance of a specific cause of death in the total mortality picture and in generating hypotheses, but is not useful or reliable in measuring the magnitude of risk[27]. However, for this population with the incomplete case ascertainment, it is difficult to interpret the PMRs since they may be the result of reporting bias towards those types of deaths. Therefore, it was determined that the results of these analyses were biased and unreliable.

Over 41% of all deaths identified were due to cancer, suggesting a reporting bias. In order to look at the relative effect of each cancer type and because the healthy worker effect should have minimal impact on cancers, PCMRs were conducted. PCMRs are useful in generating hypotheses, but because of the under ascertainment, they are not useful or reliable in measuring the magnitude of risk. The WTC RFI included deaths up to eight years beyond the WTC disaster. The calculated morality rates will give a good indication of risk only for those cancers with high fatality rates and short latency periods (the period of time between the start of the disease and when symptoms become apparent). PCMRs were elevated for melanoma, and laryngeal, kidney, bladder and brain cancers within one comparison group; but were consistently significantly elevated for ovarian cancers and multiple myeloma, one of the *a priori* hypotheses. Both of these cancers have relatively low five-year survival rates (45.4% for ovarian and 39.4% for multiple myeloma)[34]. The analyses did not identify a common source of exposure among the workers who died from these cancers. Therefore, for the population of workers that was studied, we do not believe deaths from these cancers were related to exposures at the WTC. It is thought that the multiple myeloma deaths were not associated with a reporting bias due to the increased concern raised by a publication in August 2009[35] since case identification stopped in June of that year.

The healthy worker effect is a significant factor affecting the mortality rates because the WTC responder population was involved in jobs requiring physical ability such as firefighters, law enforcement and construction workers; there was a large population of elderly volunteers that were healthier than many of similar ages; and the follow-up period was relatively short. It is not surprising that few of the SMRs were elevated and even fewer were statistically significant.

Three different comparison groups were used to try to find a comparison population that was similar to the responders and rescue workers; however, all of these populations included non-working individuals who are in general, not as healthy as working people. Ideally, a comparison population of similar workers would be utilized. Internal comparisons could also be conducted where individuals with high exposures would be compared to those with low exposures. Because WTC employment records were only received for 57% of this population, and because the number of individuals dying from each specific cause of death was relatively small, internal comparisons were not possible in this study.

Disasters, by definition, pose methodological challenges since systems are not in place to adequately track exposures or health outcomes before, during or after the disaster occurs[36]. Therefore, study designs examining health impacts can deviate from traditional epidemiology. The WTC RFI was an attempt at developing a mortality registry relying primarily on an observational research design. The WTC Health Registry provided an estimation of the size and characterization of the responder population at risk; however, it is unknown whether this characterization may be biased and whether it accurately represents the responder population as demonstrated by comparisons showing differences between these populations. It is also acknowledged that biases existed in the identification of the deaths from the various sources.

In order to more successfully complete a study such as this, there needs to be identification of the majority of responders by all participating responder organizations. This will still miss a substantial number of survivors who carry out most of the initial disaster response and those responders who are self-dispatched[37,38]; however, it would still provide a baseline population for whom long-term health effects could more easily be identified and assessed. Assisting in this process would be a cohesive human subjects review process that would allow for medical and exposure information to be shared between researchers studying the same population. Since neither of these recommendations can be used for the WTC exposed population, it is recommended that the currently established WTC medical monitoring programs and the WTC Health Registry conduct NDI matching of their cohorts on a periodic basis to examine whether there is an increased risk among their cohorts. Because there is no appropriate external population to use for comparisons, internal comparisons should be utilized wherever possible to control for the healthy worker effect. Analysis of the WTC RFI causes of death that were elevated should be conducted, even if they were not statistically significant in this project to ensure that the data limitations were not masking a true risk.

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Table 1. Characteristics of the confirmed WTC responder deaths, 2001-2009

	N	%
Sex		
Male	710	87.2
Female	104	12.8
Race		
White, not of Hispanic origin	615	75.5
Black, not of Hispanic origin	92	11.3
Hispanic	55	6.8
Other	10	1.2
Unknown	42	5.2
Age at death		
<25	7	0.9
25-34	59	7.2
35-44	155	19.0
45-54	263	32.3
55-64	217	26.7
65-74	83	10.2
75+	30	3.7
Year of death		
2001	6	0.7
2002	37	4.5
2003	52	6.4
2004	112	13.8
2005	128	15.7
2006	148	18.2
2007	155	19.0
2008	127	15.6
2009	49	6.0
Source of first report		
Newpaper/Obituary	363	44.6
Attorney	150	18.4
WTC Health Registry	224	27.5
Unions	27	3.3
Other	50	6.1
Industry at WTC		
Fire department	125	15.4
Law enforcement	125	15.4
Government	154	18.9
Volunteer	129	15.8
Medical/EMS	54	6.6
Construction	146	17.9
Other	67	8.2
Missing	14	1.7

Table 2. Standardized mortality ratios for select causes of death among the WTC responder population, 2001-2009, adjusting for age and sex

Cause of death	**US General Population**		**NYC Region[a]**		**NYC (5 boroughs)**	
	N	**SMR (95% CI)**	**N**	**SMR (95% CI)**	**N**	**SMR (95% CI)**
Overall	814	0.31 (0.29 - 0.33)	510	0.39 (0.36 - 0.43)	311	0.39 (0.35 - 0.43)
Viral hepatitis	6	0.25 (0.09 - 0.54)	5	0.25 (0.08 - 0.59)	5	0.29 (0.09 - 0.67)
Human immunodeficiency virus disease	10	0.19 (0.09 - 0.34)	8	0.14 (0.06 - 0.27)	4[b]	0.06 (0.02 - 0.16)
Cancers	342	0.58 (0.52 - 0.64)	222	0.70 (0.61 - 0.79)	129	0.68 (0.57 - 0.81)
Lip, oral cavity and pharynx	5	0.34 (0.11 - 0.79)	3[b]	0.42 (0.09 - 1.24)	2[b]	0.41 (0.05 - 1.47)
Esophageal	16	0.68 (0.39 - 1.10)	12	0.97 (0.50 - 1.69)	8	1.25 (0.54 - 2.46)
Stomach	9	0.62 (0.29 - 1.18)	7	0.57 (0.23 - 1.17)	4[b]	0.51 (0.14 - 1.30)
Colon, rectum and anus	27	0.49 (0.33 - 0.72)	19	0.59 (0.36 - 0.92)	13	0.68 (0.36 - 1.16)
Liver and bile duct	15	0.47 (0.26 - 0.77)	11	0.48 (0.24 - 0.86)	9	0.48 (0.22 - 0.92)
Pancreatic	25	0.69 (0.45 - 1.01)	18	0.89 (0.53 - 1.41)	8	0.66 (0.28 - 1.29)
Larynx	5	0.83 (0.27 - 1.93)	4[b]	0.88 (0.24 - 2.26)	1[b]	0.30 (0.01 - 1.69)
Trachea, bronchus and lung	88	0.53 (0.42 - 0.65)	55	0.78 (0.59 - 1.02)	31	0.80 (0.54 - 1.13)
Melanoma of the skin	10	0.68 (0.33 - 1.25)	6	1.04 (0.38 - 2.26)	2[b]	1.11 (0.13 - 4.01)
Breast	10	0.36 (0.17 - 0.66)	3[b]	0.18 (0.04 - 0.51)	1[b]	0.08 (0.00 - 0.44)
Ovary	5	0.60 (0.19 - 1.40)	4[b]	0.83 (0.23 - 2.13)	3[b]	0.96 (0.20 - 2.80)
Prostate	8	0.52 (0.22 - 1.02)	3[b]	0.41 (0.08 - 1.19)	3[b]	0.77 (0.16 - 2.25)
Kidney and renal pelvis	12	0.72 (0.37 - 1.26)	9	1.26 (0.58 - 2.39)	5	1.35 (0.44 - 3.15)
Bladder	7	0.68 (0.27 - 1.40)	2[b]	0.42 (0.05 - 1.51)	2[b]	1.12 (0.14 - 4.04)
Meninges, brain and other parts of central nervous system	19	0.78 (0.47 - 1.22)	15	3.14 (1.76 - 5.17)	10	1.20 (0.57 - 2.20)
Lymphoid, hematopoietic and related tissue	49	0.93 (0.69 - 1.23)	32	0.97 (0.66 - 1.37)	13	0.62 (0.33 - 1.06)
Non-Hodgkins lymphoma	18	0.99 (0.59 - 1.57)	15	1.22 (0.69 - 2.02)	6	0.70 (0.26 - 1.52)
Leukemia	20	0.91 (0.56 - 1.40)	10	0.82 (0.39 - 1.50)	4[b]	0.63 (0.17 - 1.61)
Multiple myeloma and immunological	8	0.82 (0.35 - 1.61)	5	0.91 (0.29 - 2.11)	2[b]	0.52 (0.06 - 1.87)
All other and unspecified malignancies	32	0.43 (0.29 - 0.60)	19	0.44 (0.27 - 0.69)	14	0.64 (0.35 - 1.07)
Diabetes mellitus	10	0.12 (0.06 - 0.22)	4[b]	0.09 (0.02 - 0.23)	3[b]	0.12 (0.02 - 0.34)
Cardiovascular disease	145	0.23 (0.19 - 0.27)	95	0.29 (0.23 - 0.35)	62	0.28 (0.21 - 0.36)
Hypertensive heart disease	10	0.20 (0.10 - 0.37)	9	0.22 (0.10 - 0.42)	6	0.14 (0.05 - 0.31)

Acute myocardial infarction	26	0.22 (0.14 - 0.32)	17	0.42 (0.25 - 0.68)	10	0.44 (0.21 - 0.81)
Atherosclerotic cardiovascular disease	18	0.23 (0.14 - 0.36)	13	0.24 (0.13 - 0.41)	11	0.22 (0.11 - 0.40)
All other forms of chronic ischemic	35	0.27 (0.19 - 0.37)	25	0.28 (0.18 - 0.42)	15	0.29 (0.16 - 0.47)
Other heart diseases	18	0.14 (0.08 - 0.22)	8	0.18 (0.08 - 0.36)	6	0.39 (0.14 - 0.85)
Cerebrovascular disease	21	0.27 (0.17 - 0.42)	12	0.33 (0.17 - 0.58)	7	0.36 (0.14 - 0.74)
Other disorders of the circulatory system	17	0.38 (0.22 - 0.60)	11	0.38 (0.19 - 0.68)	7	0.34 (0.14 - 0.70)
Respiratory disease	24	0.19 (0.12 - 0.28)	17	0.32 (0.18 - 0.51)	11	0.32 (0.16 - 0.57)
Pneumonia	9	0.31 (0.14 - 0.59)	5	0.23 (0.08 - 0.54)	5	0.26 (0.09 - 0.61)
Other diseases of the respiratory system	15	0.79 (0.44 - 1.31)	12	1.96 (1.01 - 3.43)	6	2.20 (0.81 - 4.78)
Alcoholic liver disease	16	0.35 (0.20 - 0.56)	11	0.58 (0.29 - 1.03)	8	0.71 (0.31 - 1.41)
Renal failure	5	0.15 (0.05 - 0.36)	3[b]	0.22 (0.04 - 0.63)	2[b]	0.55 (0.07 - 1.98)
All other residual diseases	48	0.21 (0.15 - 0.28)	31	0.29 (0.20 - 0.41)	21	0.35 (0.22 - 0.54)
Traumatic events	148	0.24 (0.20 - 0.28)	71	0.31 (0.24 - 0.39)	38	0.26 (0.19 - 0.36)
Accidents (unintentional injuries)	74	0.19 (0.15 - 0.24)	38	0.24 (0.17 - 0.33)	19	0.19 (0.11 - 0.30)
Motor vehicle accidents	51	0.33 (0.25 - 0.44)	23	0.51 (0.32 - 0.77)	8	0.48 (0.21 - 0.95)
Accidental exposure to smoke, fire and flames	12	1.83 (0.95 - 3.20)	10	3.65 (1.75 - 6.72)	9	8.50 (3.90 - 16.18)
Other and unspecified non-transportation accidents	11	0.05 (0.03 - 0.09)	5	0.05 (0.02 - 0.11)	2[b]	0.03 (0.00 - 0.10)
Intentional injuries	58	0.28 (0.21 - 0.36)	32	0.61 (0.42 - 0.87)	19	0.57 (0.35 - 0.90)
Suicides (all)	44	0.31 (0.22 - 0.41)	24	0.46 (0.29 - 0.68)	13	0.42 (0.22 - 0.72)
Suicide by firearm	23	0.34 (0.22 - 0.52)	13	0.99 (0.53 - 1.69)	7	1.42 (0.57 - 2.93)
Suicide by other means	21	0.28 (0.17 - 0.42)	11	0.27 (0.14 - 0.49)	6	0.23 (0.08 - 0.50)
Homicides (all)	14	0.20 (0.11 - 0.33)	8	8.68 (3.75 - 17.10)	6	1.30 (0.48 - 2.83)
Homicide by firearm	12	0.21 (0.11 - 0.37)	7	0.22 (0.09 - 0.45)	5	0.25 (0.08 - 0.58)
Alcohol-induced	19	0.23 (0.14 - 0.35)	14	0.31 (0.17 - 0.52)	10	0.33 (0.16 - 0.60)
Drug-induced	56	0.29 (0.22 - 0.38)	38	0.42 (0.30 - 0.57)	26	0.34 (0.22 - 0.49)
Complications of medical and surgical care	8	2.62 (1.13 - 5.14)	4[b]	1.73 (0.47 - 4.43)	2[b]	2.51 (0.30 - 9.07)

[a] Bergen NJ, Bronx NY, Essex NJ, Hudson NJ, Kings NY, Middlesex NJ, Monmouth NJ, Nassau NY, New York NY, Orange NY, Queens NY, Richmond NY, Rockland NY, Suffolk NY, Union NJ, and Westchester NY

[b] Small cell sizes may contribute to rate instability

Table 3. Proportionate cancer mortality ratios among the WTC responder population, 2001-2009, adjusting for age and sex

Cancer cause of death	US General Population		NYC Region[a]		NYC (5 boroughs)	
	N	PCMR (95% CI)	N	PCMR (95% CI)	N	PCMR (95% CI)
Lip, oral cavity and pharynx	5	1.09 (0.35 - 2.54)	3[b]	1.23 (0.25 - 3.59)	2[b]	1.08 (0.13 - 3.91)
Esophageal	16	1.04 (0.60 - 1.69)	12	1.40 (0.72 - 2.45)	7	1.79 (0.72 - 3.70)
Stomach	9	1.47 (0.67 - 2.79)	7	1.34 (0.54 - 2.77)	4[b]	1.60 (0.44 - 4.10)
Colon, rectum and anus	27	0.62 (0.41 - 0.90)	19	0.64 (0.39 - 1.00)	13	0.89 (0.47 -1.52)
Liver and bile duct	15	0.69 (0.39 - 1.14)	11	0.68 (0.34 - 1.22)	9	1.05 (0.48 - 2.00)
Pancreatic	25	1.24 (0.80 - 1.83)	18	1.40 (0.83 - 2.21)	8	2.04 (0.88 - 4.02)
Larynx	5	3.42 (1.11 - 7.99)	4[b]	2.67 (0.73 - 6.83)	1[b]	5.26 (0.13 - 29.32)
Trachea, bronchus and lung	88	0.56 (0.45 - 0.69)	55	0.68 (0.51 - 0.89)	31	0.85 (0.58 - 1.21)
Melanoma of the skin	10	1.61 (0.77 - 2.96)	6	3.41 (1.25 - 7.42)	2[b]	8.70 (1.05 - 31.41)
Breast	10	0.90 (0.43 - 1.65)	3[b]	2.05 (0.42 - 6.00)	1[b]	1.12 (0.03 - 6.26)
Ovary	5	3.55 (1.15 - 8.28)	4[b]	5.88 (1.60 - 15.06)	3[b]	9.09 (1.87 - 26.57)
Prostate	8	2.09 (0.90 - 4.12)	3[b]	2.11 (0.44 - 6.17)	3[b]	2.65 (0.55 - 7.76)
Kidney and renal pelvis	12	1.63 (0.84 - 2.85)	9	3.90 (1.78 - 7.40)	5	12.82 (4.16 - 29.92)
Bladder	7	3.18 (1.28 - 6.56)	2[b]	2.63 (0.32 - 9.51)	1[b]	6.67 (0.17 - 37.14)
Meninges, brain and other parts of central nervous system	19	0.79 (0.48 - 1.23)	15	4.87 (2.73 - 8.03)	10	2.01 (0.96 - 3.70)
Lymphoid, hematopoietic and related tissue	49	0.82 (0.61 - 1.09)	32	0.84 (0.58 - 1.19)	13	0.80 (0.42 - 1.36)
Non-Hodgkins lymphoma	18	1.30 (0.77 - 2.06)	15	1.32 (0.74 - 2.18)	6	1.12 (0.41 - 2.43)
Leukemia	20	1.40 (0.85 - 2.16)	10	1.77 (0.85 - 3.25)	4[b]	1.69 (0.46 - 4.34)
Multiple myeloma and immunological	8	5.59 (2.42 - 11.02)	5	12.82 (4.16 - 29.92)	2[b]	12.5 (1.51 - 45.15)

[a] Bergen NJ, Bronx NY, Essex NJ, Hudson NJ, Kings NY, Middlesex NJ, Monmouth NJ, Nassau NY, New York NY, Orange NY, Queens NY, Richmond NY, Rockland NY, Suffolk NY, Union NJ, and Westchester NY

[b] Small cell sizes may contribute to rate instability