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REVIEW

World Trade Center disaster: short- and medium-term health outcome

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ABSTRACT: ***World Trade Center disaster: short- and medium-term health outcome. G. Moscato, M.R. Yacoub.***

Several studies related to September 11 World Trade Center (WTC) terrorist attack have been conducted in order to monitor physical and mental health in the population at risk in the short and medium term. In this paper the main health consequences in the exposed subjects 6 years after the disaster, including ocular, gastrointestinal, respiratory and psychological effects are described and discussed.
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Introduction

The collapse of the Twin Towers at the World Trade Center (WTC) on September 11, 2001 after the terrorist attack provoked multifaceted direct and indirect consequences. A total of 2973 people lost their lives that day, including 246 on the four aircrafts, 2602 in the Towers and on the ground, and 125 at the Pentagon. As a consequence of structural damage and ensuing fires, caused by the total collapse of the towers, an unmeasured amount of toxic and irritant debris were spread resulting in human and environmental repercussions of enormous magnitude. A partial list of these materials is shown in table 1.

Health effects concerned not only the workers located at the site of the collapse, but also community residents, firefighters, police first-responders, iron-workers [1], clean-up and recovery workers at the WTC site (included persons involved in the restoration of essential services and infrastructures). The population at highest risk remains "the Ground Zero" first responders and workers, who were caught in the blackout of the collapse cloud and therefore were victim of the most intense exposure to various potentially hazardous substances. Nevertheless, Stephenson [2] highlights the lack of monitoring health consequences in a proportion of people exposed to the caustic dust and other pollutants at Ground Zero, like clean-up operators, even if some efforts were made by Research Institutes to create a Registry of all heavy equipment operators involved in the disaster site in order to allow long term monitoring of physical and mental health of such workers.

In apparent contradiction with Government announcements of safety [3], many survivors exposed to the toxic debris emanating from the site fires presented symptoms due to irritating effect of these on mucous membranes. In particular, dust particles were highly alkaline and corrosive, thus capable of causing chemical irritation of the eyes and of the upper airway tract. Gastroesophageal reflux symptoms were also described as a result of ingestion of dust and debris, with a subsequent worsening of respiratory diseases.

Several investigations have been conducted in order to describe and monitor physical and mental health in relation to the WTC disaster in a population at risk in the short and medium term. This paper reports the main results derived from these studies.

Table 1. - List of the main toxic and irritant debris at the WTC site (data derived from Ref N 26)

COMPONENTS OF DUST CLOUD
Cement dust
Glass fibers
Asbestos
Lead
Hydrochloric acid
Polychlorinated biphenyls
Organochlorine pesticides
Polychlorinated dioxins and furans
COMPONENTS OF SMOKE DERIVED FROM THE FUEL COMBUSTION
Volatile organic compounds, including benzene
Metals
Polycyclic aromatic hydrocarbons

1. Ocular effects

Thirteen percent (n = 666) of medical consultations in the sphere of a medical surveillance system including 5222 rescue workers (workers specifically assigned to rescue and recovery operations) between September 11 and October 11 were for the investigations of eye-related conditions [4]. The leading ophthalmologic symptoms reported by Ground Zero survivors were painful, burning eyes secondary to debris, corneal abrasions, and keratitis caused by exposure to smoke and chemical fumes [5].

2. Upper digestive tract effects

Several studies performed on the firefighters demonstrated an "unexpected" high incidence of gastroesophageal reflux disease (GERD) in subjects exposed to WTC dust. Prezant and co-workers [6] describe this high incidence in their study which highlights that 87 percent (287/332) of firefighters with WTC cough (see under for the definition of WTC cough) reported symptoms of GERD disease. Mechanisms for the development of GERD have been discussed, but it remains a scarcely understood aspect of that inhalational injury.

3. Upper respiratory tract effects

Lin S. and co-workers [7] described the new onset of several upper respiratory symptoms, i.e. nose irritation or burning, nasal congestion, hoarse throat or other throat irritation, sinus congestion and nose bleeding. Rates of all new-onset symptoms and persistence of these one year after 9/11 were significantly higher in the affected area.

4. Lower respiratory tract effects

Behind the expected worsening of upper and/or lower respiratory diseases, like sinusitis and/or asthma described in adults [1] as well as in children [8], an important proportion of exposed persons reported new onset symptoms.

a) Granulomatous pneumonitis

Safirstein B.H. *et al.* [9] first reported an isolated case of granulomatous pneumonitis in a 37-year-old man, a project manager working at a building located one block from the WTC. Respiratory symptoms began three weeks after the collapse and thorough investigations including lung biopsy, scanning electron microscopy and energy dispersive radiograph analysis revealed noncaseating granuloma and silica, silicates and calcium oxalates particles. A very recent paper [10] demonstrated an increased incidence of sarcoidosis or "sarcoid-like" granulomatous pulmonary disease among the Fire Department of New York rescue workers. Twenty six subjects received the diagnosis during the four years following the disaster. Moreover, the authors report that 69% of these workers (18/26) presented clinical symptoms suggestive of asthma, confirmed by objective means (bronchial obstruction, bronchodilator response and/or bronchial hyperreactivity (BHR).

b) Eosinophilic pneumonitis

Rom W.N. and co-workers reported a case of acute eosinophilic pneumonitis [11] in a firefighter exposed to high concentration of smoke and dust at the WTC site. The 38-year-old man had arrived 20 minutes after the collapse of the Twin Towers and had been working for about 16 hours per day during the following 12 days. He did not use any mechanical ventilator for most of these days. He was admitted on September 24 to a medical intensive care unit for his respiratory symptoms, i.e. cough, myalgias, fever, chest discomfort, and progressive dyspnea. Investigations demonstrated hypoxemia (PaO_2 = 53 mmHg), and bronchoalveolar lavage showed 70% eosinophils (without peripheral eosinophilia) and some asbestos fibers. After treatment with corticosteroids for 9 days, clinical and laboratory findings were clearly improved.

c) Bronchiolitis obliterans

Mann J.M. *et al*. [12] reported a case of bronchiolitis obliterans in a 42-year-old New York City Highway Patrol officer who arrived at the WTC "Ground Zero" early on September 11. He started with chest discomfort on September 12 and dyspnea worsened despite therapy with oral and inhaled corticosteroids and inhaled bronchodilator. The patient was followed for over two years with serial chest radiographs and CT scans, with normal results, while pulmonary function examinations showed a progressive deterioration. A lung biopsy performed for the persistence of exertional dyspnea showed a chronic bronchiolitis with focal obliterative bronchiolitis and rare non-necrotising granuloma. Clinical and pulmonary function improved after the addition of Azithromycin to his treatment.

d) "WTC cough" (WTCC)

A particularly prominent clinical finding was the prevalence of the "WTC cough" (WTCC) defined by Prezant *et al*. [6] as "a persistent cough that developed after exposure to the site and was accompanied by respiratory symptoms severe enough for Fire Department of New York City (FDNY) physicians to place the worker on medical leave for at least four consecutive weeks". During the six months after the collapse these authors studied a large group of firefighters exposed to WTC site in whom a severe cough developed. They focused their attention on clinical (WTCC, no WTCC) and functional outcomes (BHR/ no BHR), according to the level of exposure. The peak incidence was in late October-early November, i.e. 5-6 weeks after the disaster. The main clinical and functional characteristics are reported in

tables 2 and 3. A large majority of the 332 firefighters with WTCC reported cough, dyspnea, sore throat, gastroesofageal reflux and chest discomfort. Gastroesophageal reflux symptoms, reported by subjects in a questionnaire, had a surprisingly high incidence in all exposed groups. The firefighters with WTCC had reduced lung function, as indicated by spirometry findings performed after

Table 2. - Presence of WTCC and of Bronchial hyperresponsiveness to Metacholine in the four exposure groups (data derived from Ref N 6)

Level of exposure	**N**	**WTCC**	**BHR**	
			subjects without WTCC (tested n = 102)	**subjects with WTCC (tested n = 249)**
High (present at WTC collapse)	1636 (16%)	128 (8%)	18/77 (23%)	
Moderate (present within first 2 days after WTC collapse	6958 (69%)	187 (3%)	2/25 (8%)	154 (62%)
Low (present within 3-7 days after WTC collapse)	1320 (13%)	17 (1%)	0	
No (not present within first 2 weeks after WTC collapse)	202 (2%)	0	0	
Total	10116	332	20/102 (19.6%)	154 (62%)

Table 3. - Main characteristics of firefighters with and without WTCC (data derived from Ref N 6)

	WTCC	**Cough (n = 295)**
Age (years)	43 ± 7	41 ± 7
Time elapsed since assumption at FDNY workforce (years)	15 ± 7	13 ± 6
Clinical characteristics	Productive cough; black to grayish sputum, with pebbles or particles within 24 hours after exposure Other symptoms: exertional dyspnea, nasal congestion, nasal drip, sore throat, gastro esophageal reflux symptoms	Cough within 24 hours after exposure
Spirometry	Significant decline of FEV_1% and FVC% in the 4 exposure groups	Normal value of FEV_1% and FVC% No difference between before and after the collapse
BHR to Mch	47/196 tested (24%)	20/102 tested (19.6%)
Reversibility test	149/237 tested (63%)	Not determined
Use of respiratory protection	Rarely or not used by 93% of firefighters the day of collapse Rarely or not used by 85% of firefighters the day after the collapse Rarely or not used by 76% of firefighters on second through 6 days after the collapse ALWAYS NOT APPROPRIATE TYPE OF MASK Frequent use of appropriated respirators since 2 weeks after the collapse	Rarely or not used by 78% of firefighters during the first week after the collapse No difference between the different exposure groups

the collapse, without significant differences among the four exposure groups. Forty seven of 196 WTCC tested firefighters (24%) had BHR. The risk of BHR and WTCC was associated with intensity of exposure.

The same group of authors [13] conducted a prospective longitudinal study in order to determine whether BHR was present, persistent and correlated with the level of exposure, using a representative sample of 179 firefighters (151 exposed [102 highly exposed, 49 moderately exposed] and 28 not exposed) stratified on the basis of initial exposure intensity, without taking into consideration respiratory symptoms. At the time of enrollment, none of the subjects fulfilled the criterion of WTCC. All subjects underwent Mch test to determine BHR at $t = 0$ (first post-WTC challenge test) and at one, three and six months after the toxic exposure. During the first assessment ($t = 0$) 32/102 (31%) highly exposed and 5/49 (10%) moderately exposed subjects presented BHR. The percentage of BHR at subsequent time points is indicated in table 4. In highly exposed workers, the provocation concentration of Mch causing a fall of $FEV_1\% \geq 20\%$ ($PC_{20}FEV_1$) decreased by 46% from month 1 to month 6, indicating a worsening of BHR during this lapse of time. After adjustment for smoking habit and bronchial obstruction, the risk to be hyperreactive in highly exposed subjects was 7.3 times if compared with the other two groups at 1 month, 6.3 times at 3 months and 6.8 times at 6 months. Furthermore, the authors found that BHR persistence at six months could be predicted by the finding of BHR at month 1 and 3. At six months, 123/151 (69%) exposed firefighters were re-submitted to Mch challenge. Out of them 20/123 (16%) received a diagnosis of reactive airways dysfunction syndrome (RADS), [17/83 re-tested in the highly exposed group (20%) and 3/40 re-tested in the moderately exposed group (8%)].

RADS has been described since 1985 by Brooks *et al*. [14] as the development of asthma-like illness within 24 hours after a single exposure to high levels of an irritating vapor, fume or smoke. In most instances, the exposure occurs in the workplace accidentally (accidental exposure to a high concentration of an irritating agent) or in case of limited air exchange in the area. The disease is characterised by: 1) a compatible history of a massive exposure to an irritant agent, 2) asthma-like symptoms occurring within 24 hours after the accidental exposure, 3) BHR, and 4) persistence of either symptoms either BHR for at least 3 months, often several years after the incident.

The appropriateness of the diagnosis of RADS in subjects involved in the WTC disaster with persistent respiratory symptoms and BHR raised a lively discussion among experts. An editorial accompanying the article of Banauch *et al*. [9] on the American Journal of Respiratory and Critical Care Medicine Nemery [15] endorsed this diagnosis, highlighting two novel aspects of the disease shown by the study, i.e. that RADS affected people may not require immediate medical care and hospitalisation, and that RADS may occur as an outcome of injury by particulates. In a subsequent letter to the same Journal, Truncale and Brooks [16] expressed their disagreement, because exposure characteristics (particles, with a size too large to be inhaled into the lung) and clinical findings (no need for short term medical care) did not fulfill the original diagnostic criteria of RADS described by Brook *et al.* in 1985 [14] (single high-level exposure to an irritant gas, fume or vapor, and short-term need of medical attention for the acuity of respiratory symptoms onset). In the opinion of Truncale and Brooks that entity should better have been described as “non allergic asthma” [17] occurring in a subgroup of susceptible individuals.

Prezant and Banauch [12] replied that in their opinion, although not completely fulfilling the original definition, that entity could appropriately be included in RADS because it met all the clinical criteria characterising the disease. They also added that the alkaline nature of WTC dust, which has been well documented, qualifies the dust as irritating and concluded that whatever the disease is called (RADS or non allergic asthma) what is important is to acknowledge that particulate matter can cause this problem, and that BHR was for the most part persistent in the severely exposed group. In our opinion, the circumstances of the event (exceptional acute inhalational accident) and the compatible clinical features seem quite adherent to the current concept of RADS, which is considered the most definitive form of non allergic, irritant induced occupational asthma [18].

5. Psychological effects

Another crucial issue in human being after the disaster was the psychological outcome in directly exposed, as well as in indirectly exposed individuals. Three months after the terrorist attack, Yehuda [19] focused on this problem in a review on post-traumatic stress disorder (PTSD). A traumatic event can be defined by means of its capacity to provoke fear, helplessness or horror in response to

Table 4. - Presence of Bronchial hyperresponsiveness to Metacholine at subsequent time points after the WTC collapse (data derived from Ref N 13)

	1 month	3 months	6 months
Highly exposed (%)	19/77 (25%)	19/80 (24%)	21/76 (28%)
Moderately exposed (%)	2/25 (8%)	3/44 (7%)	3/36 (8%)
Control (%)		1/28 (3.5%)	

the threat of injury or death (diagnostic and statistical manual of mental disorders, 4th Edition). People who are exposed to such events are at increased risk of PTSD [20], as well as for major depression, panic disorder, generalised anxiety disorder and substance abuse, compared with those who have not experienced traumatic event [21]. The author indicates that on the basis of prevalence of PTSD after previous terrorist attack, it was possible to predict that approximately 35% of directly exposed people would have developed such a disorder. As a matter of facts, directly exposed individuals presented PTSD at a rate of 20% as confirmed by two different studies [22, 23].

Conclusion

Exposure to an unmeasured amount of toxic and irritant debris on the occasion of the WTC collapse implied many human and environmental repercussions of enormous magnitude. Short and medium term health effects particularly involved respiratory tract and mental health. Long-term clinical sequelae remain to be determined, in particular the progression of respiratory diseases and/or dysfunctions, the negative effects on fetal development and the new-onset of asbestos-related diseases [24]. A crucial point is that no rescue plan existed for such an eventuality, and that contributed to the magnitude of negative effects of WTC disaster on directly and indirectly exposed subjects. Despite the exceptionality of the event, some recommendations may be extrapolated from that dramatic experience.

Despite the exceptionality of the event, some reccomendations may be extrapolated from that dramatic experience. Firstly, all diseases described in WTC exposed persons m ay also be found in individuals exposed to hard work conditions, therefore these persons should by considered at high risk of respiratory injuries and should be submitted to regular health surveillance programmes [15]. Secondly, people at risk of toxic inhalation should always be provided with adequate respiratory protection. Even if respirators are never fully protective, they sould be selected properly [25] in order to furnish the most effective protection.

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