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World Trade Center Cough Syndrome and Its Treatment

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Abstract To date, the main respiratory health consequence from the collapse of the World Trade Center (WTC) on September 11, 2001 has been the "WTC Cough Syndrome" (chronic rhinosinusitis, asthma, and/or bronchitis, often complicated by gastroesophageal reflux dysfunction). Syndrome incidence and severity have been linked to WTC dust exposure intensity. While it is too early to ascertain long-term effects of WTC dust exposure, effective treatment guidelines have been designed through a collaborative effort by the three established centers of excellence for WTC medical monitoring and treatment and the WTC Registry. These treatment recommendations are described here.

Keywords World Trade Center · Asthma · Cough · Rhinosinusitis · Gastroesophageal reflux

Introduction

On September 11, 2001, aerial terrorist attacks on the World Trade Center (WTC) led to its collapse producing a plume of dust and ash that spread throughout lower Manhattan and beyond [1]. Concurrent with this physical destruction, combustion of approximately 91,000 L of aircraft fuel ignited numerous structural fires, many of which smoldered until mid-December 2001. An estimated 525,000 people, including over 90,000 workers, were potentially exposed to the resulting pollutants during the collapse, rescue, recovery, and cleanup efforts [2, 3]. Pulverized building materials predominated in the initial period postcollapse, while combustion-derived pollutants increased as rescue, recovery, and cleanup progressed [4]. The fires at the site created toxic combustion products such as polycyclic aromatic hydrocarbons (PAHs), dioxins, volatile organic compounds, and various other known carcinogenic compounds [1, 4–7]. Contaminants such as asbestos, hydrochloric acid, PCBs (polychlorinated biphenyls), silica, and heavy metals were found in the dust and ash resulting from the WTC collapse [1, 4–7].

Evidence is clear that the upper and lower respiratory symptoms experienced by many of those who were exposed were primarily due to respired dust. There was an exposure-response gradient, with the highest symptom prevalence found in those directly exposed to the dust cloud, arriving during the morning of 9/11/01 [8–10]. Ninety-five percent of the respirable WTC dust was composed of large particulate matter ($\geq$10 μm in diameter) [1]. Particles of this size have conventionally been thought to be filtered by the upper respiratory tract, rarely entering the lower respiratory structures [4]. However, there are a number of reasons to expect lower airways to be at risk from the dust cloud. First, it has been shown that alkaline dust impairs nasal clearance mechanisms, and most WTC dust samples had a pH greater than 10 [11]. Second, the nasal filtration system is optimally functional during restful breathing. However, WTC rescue/recovery workers, as a consequence of their work activities (moderate- to high-level physical exertion), were breathing at high minute ventilations where mouth breathing predominates. Finally, although only a small percentage of particles larger than 10 μm tend to impact in lower airways, the huge

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magnitude of the WTC dust cloud meant that a small percentage of particles that penetrated deep into the lung may have added up to a significant exposure [12]. In fact, in a study of 39 firefighters from the Fire Department of the City of New York (FDNY) 10 months after exposure [12], it was demonstrated the WTC dust did make it down into the lower airways as particulate matter (>10 μm), consistent with WTC dust, with associated increases in inflammatory cells and cytokines in induced sputum.

World Trade Center Cough Syndrome is a chronic cough syndrome, thought to be a consequence of upper and lower respiratory diseases. Upper respiratory tract disease, usually but not always manifested as cough, has been due to reactive upper airways dysfunction syndrome (RUDS), chronic rhinosinusitis, and/or gastroesophageal reflux dysfunction (GERD). Lower respiratory tract disease, also most commonly manifested as cough but often with associated chest tightness, shortness of breath, and exercise intolerance, has been due to reactive (lower) airways dysfunction syndrome (RADS) or irritant-induced asthma, types of asthmatic bronchitis that often lead to chronic obstructive airways diseases, and, in a few cases, parenchymal lung diseases, such as sarcoidosis, pulmonary fibrosis, and bronchiolitis obliterans.

World Trade Center Cough

During the first five years post-9/11/01, high rates of upper and lower respiratory irritant symptoms, primarily cough, have been described in at least seven WTC rescue/recovery worker groups: (1) In 13,854 previously healthy, exposure-stratified FDNY rescue workers, self-reported daily cough was present in 99% on day 1 (9/11/01), 53% during the first month postcollapse, 46% during the first year postcollapse, and 31% during the next 2–4 years [9]. (2) In the NY/NJ WTC consortium's non-FDNY cohort, consisting of police, sanitation, transportation, construction, and other workers, 69% of the first 9,442 responders reported new or worsened upper (62.5% of 9,442) or lower (46.5% of 9,442) respiratory symptoms during their WTC-related efforts, with symptoms persisting to the time of examination in 59% (on average 8 months after they stopped their rescue/recovery/cleanup activities) [16], and in another study they found that in the previously asymptomatic group, 44% developed lower respiratory symptoms during their work at the WTC site. Analysis again demonstrated that the incidence of lower respiratory symptoms was directly related to arrival time [10]. (3) Of 240 previously healthy NYC Emergency Service Unit (ESU) police officers, 77% had upper and/or lower respiratory symptoms during the first 5 months postcollapse [17]. (4) In 471 NYC police officers (426 with no pre-9/11 chronic respiratory disease), 44% reported having a cough at both 1 and 19 months postcollapse but over this same time interval reported increasing prevalence of shortness of breath (18.9-43.6%) and wheeze (13.1–25.9%) [18]. (5) Of 96 ironworkers, 77% had upper and/or lower respiratory symptoms 6 months postcollapse [19]. (6) In a study of 269 transit workers, those caught in the dust cloud had significantly higher risk of persistent lower respiratory and mucous membrane symptoms [20]. (7) In 183 cleanup workers, the prevalence of upper and lower respiratory symptoms increased as the cumulative number of days spent at WTC increased [21]. Respiratory consequences have also been noted in WTC studies on community residents, children, and office workers in lower Manhattan [22–24]. A WTC Health Registry study confirmed that of 8,418 adults who were caught in the collapse on 9/11, 57% experienced new or worsening respiratory symptoms after the attacks [3].

The World Trade Center cough syndrome was first reported by the FDNY WTC Medical Monitoring and Treatment Program [8]. During the first 6 months following the WTC attack, FDNY Bureau of Health Services described a syndrome of clinical, physiologic, and radiographic abnormalities due to significant unrelenting airway inflammation in an initial cohort of 332 FDNY rescue workers. Because so many were affected, the case definition specified a persistent cough severe enough to require at least 4 weeks of continuous leave (medical, light duty, or retirement) with onset during the 6 months following the WTC collapse. More recently, FDNY reported that between 9/11/01 and 6/30/07, 1,847 (~13%) FDNY rescue workers had met this strict case definition and over 728 have qualified for permanent respiratory disability benefits [9]. Clinical symptoms were consistent with aerodigestive mucosal inflammation (rhinosinusitis, bronchitis, acid reflux), with a surprisingly high rate of gastroesophageal reflux complaints (87%) [8]. Physiologic evidence of asthmatic airway inflammation in those with the syndrome included response to bronchodilators (63% of those diagnosed) and nonspecific bronchial hyperreactivity determined by methacholine challenge testing (24% of those diagnosed), indicating that these rescue workers had a high rate of asthmatic physiology [8]. Radiologic confirmation of airway inflammation in these firefighters included CT scan evidence of air trapping (abnormal retention of air in the lungs after expiration) in 51% and bronchial wall thickening in 24% [8]. The incidence of this syndrome was correlated with WTC dust exposure intensity (estimated by initial arrival time at the WTC site). Nearly all of the firefighters and EMTs who developed WTC cough syndrome had been exposed during the first 48 h postcollapse and most had been exposed during the morning of 9/11 [8, 9].

Reactive Upper Airways Dysfunction Syndrome (RUDS) and Chronic Rhinosinusitis

RUDS is defined as chronic rhinosinusitis (nasal and/or sinus inflammation) initiated by high-level exposure to inhaled irritants, with recurrence of symptoms after re-exposure to irritants. Diagnosis depends largely on symptoms without quantifiable diagnostic tests. High rates of upper airway symptoms have been described in various occupational groups involved in rescue, recovery, and cleanup at the WTC site, with higher prevalence in those who were more highly exposed. In 13,854 previously healthy FDNY rescue workers, stratified for severity of exposure by arrival time at the WTC site, self-reported sinus congestion and/or drip was present in 80% on day 1 (9/11/01), 40% during the first month postcollapse, 25% during the first year postcollapse, and 32% during the next 2–4 years [9]. In this same group, sore or hoarse throat was reported in 63% on day 1 (9/11/01), 54% during the first month postcollapse, 46% during the first year postcollapse, and 22% during the next 2–4 years [9]. An exposure intensity gradient was evident for those with initial and persistent symptoms. In the NY/NJ consortium of non-FDNY rescue workers/volunteers, 66% of those directly exposed to the dust cloud reported upper respiratory symptoms such as congestion, runny nose, headache, sinus pain, sore throat, ear pain or blockage, and hoarse voice [10]. In 96 ironworkers, who were on the pile from the afternoon of 9/11, usually on long shifts and without respiratory protection, 52% had persistent sinus complaints, with corresponding physical signs such as nasal mucosinusitis and swollen turbinates in at least 30% of the cohort [19]. In 240 NYPD ESU officers between 1 and 5 months after the collapse, 41% had persistent nasal and/or throat symptoms [17]. The main diagnosis associated with these symptoms is chronic rhinosinusitis, but there is considerable overlap with asthmatic and GERD symptoms and the literature pre- and post-WTC clearly shows that successful treatment requires a coordinated approach to treat all of these related conditions.

Gastroesophageal Reflux Disease (GERD)

In the general population, GERD has been well described as a causal or exacerbating factor for inflammatory airway diseases such as asthma. Among FDNY rescue workers, several studies have now described high rates of reflux disease. Eighty-seven percent of 332 FDNY rescue workers diagnosed with WTC cough reported GERD requiring treatment [8], and in a study of 179 exposure-stratified FDNY rescue workers, 45% of those who were found to be hyperreactive by methacholine challenge testing (1–6 months postcollapse) reported GERD [27].

Reports of GERD were not limited to FDNY rescue workers, as the NY/NJ consortium of non-FDNY rescue workers/volunteers has also reported that in their first year of operation, 54% of their patients had GERD [10]. The WTC Health Registry reported that of a cohort of 8,418 adult survivors caught in the collapse, 23.9% reported heartburn or acid reflux [3]. Clinical experience at all three WTC Clinical Centers of Excellence (FDNY, Mt. Sinai Consortium, and Bellevue Hospital) suggests that many responders have persistent symptoms that have required prolonged or even chronic use of medications to control acid production (personal communications from Drs K. Kelly, S. Levin, and J. Reibman). Though no clear mechanism for the development of GERD has been described in this setting, ingestion of airborne particulate WTC material or particulates cleared from the airways, along with stress, dietary triggers, and medication use (GERD is increased with certain medications used for WTC-related conditions) are the presumed causes, often acting in combination. Consensus literature pre- and post-WTC clearly shows that without successful GERD treatment there can be no or only minimally effective treatment for upper and lower respiratory conditions such as sinusitis and asthma [25, 26].

Reactive (lower) Airways Dysfunction Syndrome (RADS) and Asthma

Occupational RADS is defined as persistent respiratory symptoms and nonspecific airway hyperreactivity in patients with a history of acute exposure to an inhaled agent (gas or aerosol) and no prior history of allergies, smoking, or asthma [32]. The definition of RADS can usefully be extended in the WTC context to include those with repeated irritant exposure who have developed irritant-induced asthma. RADS can and often does progress to irreversible lower airways obstructive disease.

In a sample of FDNY rescue workers whose bronchial hyperreactivity was measured 6 months after 9/11/01, those who arrived at the WTC site on 9/11 were 7.8 times more likely to experience bronchial hyperreactivity than those firefighters who arrived at the site at a later date and/or had lower exposure levels [27]. In this FDNY study, RADS emerged in 20% of highly exposed (present during the morning of collapse) and 8% of moderately exposed rescue workers (present after the morning of 9/11 but within the first 48 h) [27]. Consistent with human observational studies, mice acutely exposed to high levels of WTC particulate matter developed pulmonary inflammation and airway hyperreactivity [34]. Findings in FDNY rescue workers over the first 2 years are consistent with the evolving non-WTC scientific literature indicating that

RADS with documented continuing bronchial hyperreactivity can persist in individuals even after exposure had ceased and even with appropriate therapy [4, 29, 30]. In the first year of the NY/NJ Consortium Program for non-FDNY rescue workers/volunteers, it was found that 45% reported symptoms consistent with lower airway disorders, including asthma and asthma variants [16]. The WTC Registry has published its findings on self-reported "newly diagnosed asthma (post-9/11/01) by a doctor or other health professional" in WTC rescue and recovery workers [35]. Of the 25,748 WTC workers without a prior history of asthma, newly diagnosed asthma was reported by 926 workers, for a 3-year incidence rate of 3.6%, or 12 times higher than the expected rate of 0.3% in the general adult population [36]. Increased incidence of newly diagnosed asthma was associated with (a) being caught in the dust cloud on 9/11/01, (b) earlier arrival time relative to the collapse, (c) work on the pile, and (d) cumulative exposure (especially greater than 90 days) [35]. When all of the above factors were adjusted for in a multivariate analysis, occupation and work tasks were not significant predictors of risk [35].

Pulmonary function declines or abnormalities were significantly related to WTC exposure intensity (based on arrival time) in FDNY and non-FDNY workers. This remained true even after accounting for preexisting disease and/or cigarette smoking [8, 10, 27-31]. For 12,079 FDNY rescue workers in the first year post-WTC, a significantly greater average annual decline in forced expiratory volume in 1 second (FEV_1) of 372 ml was noted in the first year post-9/11/01 when compared to the normal annual decline of 31 ml found in the 5 years of pre-WTC testing—a substantial accelerated decline in pulmonary function [31]. Similar findings were found for the forced vital capacity (FVC). In the NY/NJ consortium report on 8,384 non-FDNY workers/volunteers, 28% had abnormal pulmonary function test results [10]. They also found that a low FVC (a measure of lung capacity) was five times more likely among the nonsmoking portion of their cohort than expected in the general U.S. population (which includes smokers and nonsmokers) [10]. Overall, WTC dust exposure intensity was related to lower FVC and a higher rate of pulmonary function test abnormalities [10], demonstrating that WTC exposure had a substantial impact on lung function. Studies in both cohorts (FDNY and non-FDNY) are currently underway to determine the course of pulmonary function over the next 5 years post-WTC, specifically, whether it has improved, stabilized, or declined and if there are differences in clinical course within or between the cohorts and which factors might be predictive of favorable or unfavorable outcome.

For NYC residents, in a telephone survey performed 5–9 weeks after 9/11, 27% of known adult asthmatics questioned said that they experienced more severe asthma symptoms in the weeks following the attacks [22]. In a post-9/11/01 study of Battery Park residents (located adjacent to WTC) who did not report a prior history of asthma, increased respiratory symptoms were reported and airway hyperreactivity was demonstrated (methacholine challenge testing) [23]. A study of Chinese children found increased asthma medication use in a clinic located near WTC compared with a clinic located in Queens, with similar patients and physician staffing [24]. A survey of Medicaid patients during the first 3 months postcollapse (9/11/01 to 12/31/01) showed a significant increase in self-reports of worsening asthma in both lower Manhattan and western Brooklyn, and according to the Medicaid Encounter Data System (MEDS), those who reported worsening of their asthma did increase their use of asthma healthcare services [37].

Parenchymal Lung Diseases

Reports have shown a higher than expected rate of sarcoidosis or sarcoid-like granulomatous lung disease in FDNY rescue workers [38]. Environmental causes of sarcoidosis or sarcoidosis-like granulomatous disease are well established [39]. In the first 5 years post-WTC (9/11/01 to 9/10/06), pathologic evidence consistent with new-onset sarcoidosis was found in 26 FDNY rescue workers, all with intrathoracic adenopathy (enlarged lymph nodes) and 6 (23%) with additional disease outside the chest [38]. Thirteen were identified during the first year post-WTC (yielding an incidence rate of 86/100,000) and 13 during the next 4 years (yielding an average annual incidence rate of 22/100,000 compared with 15/100,000 for the FDNY personnel during the 15 years pre-WTC and 5–7/100,000 for a male Caucasian population) [40].

To date, with the exception of sarcoidosis, interstitial lung diseases have not been reported in any case series or population study of WTC workers, but single-case reports of eosinophilic pneumonia [41], bronchiolitis obliterans [42], and granulomatous pneumonitis [43] have been described. The lay press has reported at least four case fatalities in non-FDNY WTC-exposed subjects due to interstitial pulmonary fibrosis, sarcoidosis (with cardiopulmonary involvement), and granulomatous pneumonitis [44].

The Impact of WTC Exposure Time on Respiratory Disease

For upper and lower respiratory illnesses, given the high volume of aerosolized, respirable dust on 9/11/01 and the

lack of appropriate respiratory protection early on [25, 35], it is not surprising that arrival time provides the best practical measure for a WTC exposure-response index. For nearly all of the FDNY rescue workers, the WTC cough has occurred primarily in those who arrived during the first 48 h after the collapse, with the greatest incidence in those arriving during the morning of the collapse [8–10, 27–31]. This is not to say that there is no one in the FDNY WTC cohort with the WTC cough whose first exposure occurred more than 48 h postcollapse. In fact, a recent WTC Registry study on newly diagnosed (post-9/11/01) asthma in rescue and recovery workers showed an effect of cumulative exposure (especially greater than 90 h), even after controlling for initial dust cloud exposure and early arrival time [35]. Aerosolized dust was resuspended during the rescue/recovery operations and during cleanup of surrounding interior spaces, and fires continued to burn until mid-December 2001.

Diagnosis and Treatment

As this review is written primarily for the specialist, the goal of this section is not to review respiratory diagnosis, treatment, and patient management strategies in general but rather to concentrate on those aspects that might be unique or specific to the WTC or for that matter nearly any disaster with significant exposure to respirable particulates and combustion byproducts. The patient history should include questions to document prior and current exposures (environmental and occupational), the intensity and duration of exposure(s), the temporal relationship of symptoms to exposure, and whether these symptoms were new in onset or, for those with preexisting disease, whether they represent acute or chronic exacerbations. Strategies for evaluating the intensity of exposure include completing a timetable recounting exposure, the time of first exposure, the time of last exposure, the number of hours and days exposed, the individual's location during exposure, a description of specific activities during exposure, and the type and extent of use of respiratory protection. Physical exam should focus on all areas of potential exposure, including skin, eyes, mucous membranes, upper and lower airways, lung, and any other exposure specific sites.

An important consideration when obtaining the medical history is accounting for the "healthy-worker effect." Because rescue workers are generally healthy and physically active prior to exposure, the severity of their symptoms and findings may be different than the general population. Postexposure, they may remain asymptomatic at rest or even with mild exercise. Changes from baseline and provocability (exercise, irritant exposures, changes in temperature and humidity) may be more important. Attention should be paid to the emotional impact of not only the exposure itself but also of the development of respiratory and physical impairments that may have resulted from the exposure to the mentally and physically stressful environment. Because post-traumatic stress is a common complication, some assessment of prior mental health history, current stress, support system, and resilience is important. Mental health issues and concerns may complicate WTC cough treatment and adherence with medication use.

Diagnostic Testing

Initial pulmonary function evaluation includes spirometry. Because these records may be used for diagnosis, treatment, and litigation, careful attention to quality control should be maintained. Postbronchodilator spirometry can be part of this initial evaluation or can be reserved for those patients with (1) symptoms, (2) spirometry that is abnormal (<80% predicted) or even at the lower limits of normal (healthy-worker effect) or (3) show a significant decrease from prior spirometry (if available). Abnormalities in pulmonary function should be further investigated as clinically indicated with determination of lung volumes, diffusion, bronchodilator response, nonspecific bronchial reactivity, and/or chest CT imaging as resources allow. A restrictive impairment (normal to supranormal FEV_1/FVC ratio) with significant improvement after bronchodilator administration [8, 10, 17], hyperreactivity after methacholine challenge testing [8, 27, 31], normal lung volumes [8], and normal diffusion [8] have been described after inhalation exposures. For these reasons, we believe it is more accurate to classify this finding as "pseudorestriction" until further diagnostic testing is performed. This may be the result of mucous impaction, air trapping, or other undetermined pathophysiology. Predisaster exposure, many may have had above-normal pulmonary function when expressed as percent predicted and, therefore, use of cutoff points to judge for "normality" in this population should be carefully and individually evaluated. This fact is highlighted by the NYC firefighter WTC study [8, 31]. For most firefighters spirometry results obtained after WTC exposure were above the lower limits of predicted normal for the general population but when compared to their own individual spirometry results obtained preexposure, significant losses in pulmonary function were noted and the decrease demonstrated a dose-intensity effect, with the greatest decrease observed in those present on 9/11/01 during the morning of the collapse [31]. Given the unfortunate likelihood that first responders may suffer future exposures, we recommend that all receive annual "baseline" spirometry as part of their general health monitoring.

Other Pulmonary Functions

In symptomatic patients with normal or near-normal spirometry results and symptoms following the disaster consistent with hyperreactivity or asthma, the methacholine challenge test should be considered if a formal diagnostic test is required. If formal diagnostic proof is not required for legal, disability, or research purposes, most physicians reserve this test for symptomatic patients who do not report classic symptoms or who fail to report or demonstrate a response to bronchodilators. Under any circumstance, challenge testing is contraindicated due to safety considerations when spirometry shows anything less than minimal abnormalities [33]. In patients who do not report symptoms consistent with hyperreactivity or asthma or who have significant abnormalities on spirometry or chest imaging, pulmonary function tests, including full-lung volumes and diffusing capacity, are recommended as the next diagnostic test after spirometry and instead of methacholine challenge testing, especially if hypoxic or restrictive disease is suspected.

Chest Imaging

In asymptomatic individuals, chest radiographs generally find no acute abnormalities. However, there may be widespread interest among those exposed to have a chest radiograph as a new baseline. In symptomatic patients, chest radiographs and CT scans have been reported to show bronchiectasis, bronchiolitis obliterans, atelectasis, lobar consolidation, and interstitial pneumonitis (hypersensitivity, eosinophilic pneumonitis, granulomatous disease, and fibrosis) [4]. Inspiratory and expiratory CT scans have been used to show air trapping, bronchial wall thickening, and mosaic attenuation [8]. Because the clinical utility of these findings in a nonresearch setting remains unclear, we recommend that inspiratory and expiratory CT scans of the chest be reserved for individuals with significant unexplained symptoms, hypoxia, or reduced total lung capacity (TLC) or diffusion (DLCO). Another area of intense research is the use of CT scans of the chest for lung cancer screening [45]. Their future use in high-risk patients (high exposure; tobacco smokers) might be a consideration depending on the results of soon to be completed lung cancer screening studies in tobacco smokers from the general population.

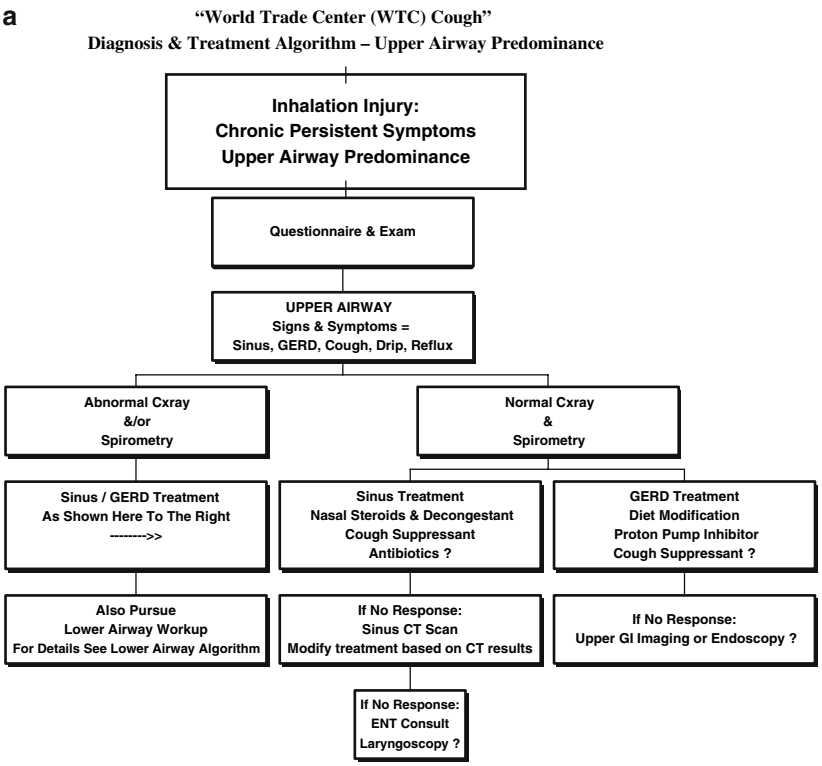
Invasive Diagnostic Methods

Induced sputum, bronchoalveolar lavage, and/or biopsy following exposure in asymptomatic and symptomatic rescue workers have been used to demonstrate increased markers of inflammation and particle deposition exposure [12, 41]. While these measures may have value in a research setting, they have limited diagnostic or prognostic value. In a clinical setting, bronchoscopy should be performed on those with significant abnormalities on chest imaging or perhaps when there is failure to respond to therapy. Sinus CT scan and direct laryngoscopy are recommended in those with chronic rhinosinusitis unresponsive to medical treatment for at least 3 months [46]. Gastroesophageal endoscopy is recommended for those with GERD either unresponsive to medical treatment or with reoccurrence after 2-3 months of therapy [47].

Treatment

Not many references describing the treatment of WTC or disaster-related chronic cough or dyspnea have been published. Recently, consensus treatment guidelines have been published as a joint collaborative effort between the three WTC Centers of Excellence (FDNY, NY/NJ consortium coordinated by MT. Sinai Medical Center, and the Environmental Health Center at Bellevue Hospital) and the WTC Registry [26]. The recommended approach includes a comprehensive plan of synergistic care treating the upper and lower airways with (a) nasal/sinuses with nasal steroids and decongestants (Fig. 1A), (b) gastroesophageal reflux with proton pump inhibitors and dietary modification (Fig. 1A), and (c) the lower airway with bronchodilators, corticosteroid inhalers, and leukotriene modifiers (Fig. 1B). For the minority that uses tobacco products, a multimodality tobacco cessation program should be instituted [49] to improve treatment success rates and to reduce the incidence of late-emerging diseases such as malignancy and cardiac and cerebral vascular diseases. Most patients have reported symptoms and required treatment for involvement of at least two of the above organ systems. Our experience has proven the multicausality of respiratory symptoms in a disaster-exposed population, with contribution of any combination of upper and lower respiratory processes. When the clinical presentation is atypical (e.g., interstitial lung disease) or there is failure to respond after approximately 3 months of treatment, we recommend additional invasive diagnostic testing such as chest CT, bronchoscopy, sinus CT, laryngoscopy, and/or endoscopy [25, 26, 46–48].

As the WTC dust cloud was unique in its magnitude and potential toxic exposure, prior experience does not allow reliable prediction of the long-term risk of late-emerging diseases or the relative importance of acute high-level vs. cumulative low-level exposures without carefully designed long-term monitoring and treatment programs. Our initial



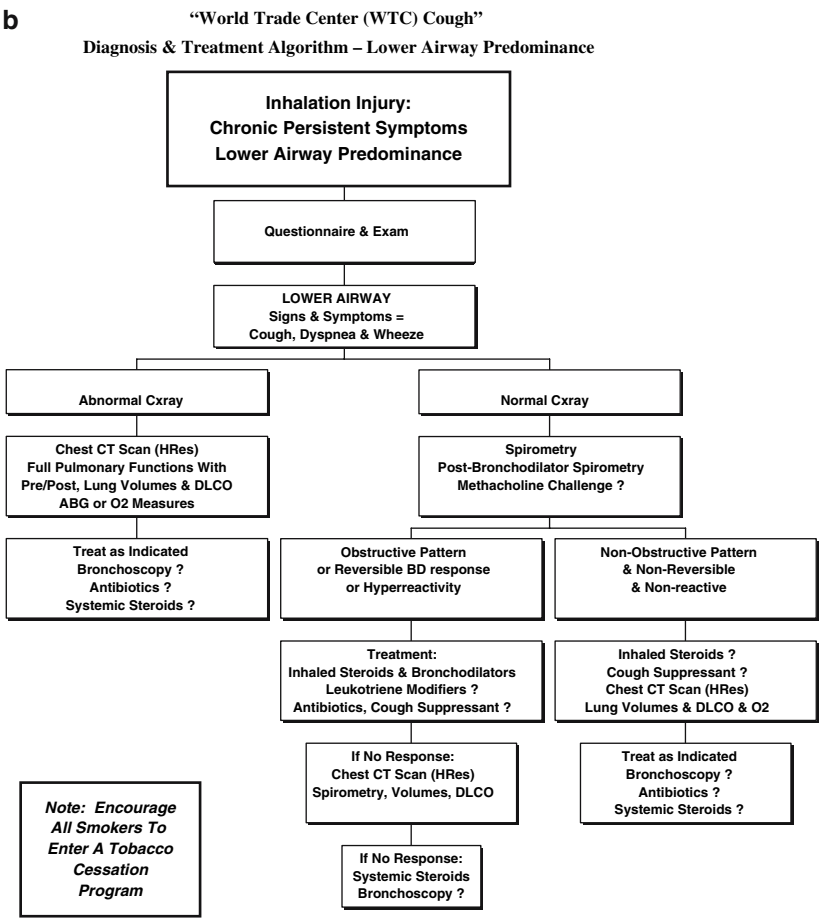


Fig. 1 **A** Treatment algorithm for WTC cough when presentation suggests that the primary causes are upper airway–related: chronic rhinosinusitis and/or gastroesophageal reflux disorder. **B** Treatment algorithm for WTC cough when presentation suggests that the primary causes are lower airway–related: obstructive airways (e.g., asthma, bronchitis) or restrictive (parenchymal diseases)

effort clearly shows the importance of a structured monitoring program leading to early diagnosis and treatment.

References

1. Lioy PJ, Weisel CP, Millette JR, Eisenreich S, Vallero D, Offenberg J, Buckley B, Turpin B, Zhong M, Cohen MD, Prophete C, Yang I, Stiles R, Chee G, Johnson W, Porcja R, Alimokhtari S, Hale RC, Weschler C, Chen LC (2002) 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 110:703–714
2. Prezant DJ, Levin S, Kelly K, and Aldrich TK (2007) Upper and Lower Respiratory Diseases after Occupational and Environmental Disasters Mt. Sinai Med J (in press)
3. Brackbill R. Thorpe L, DiGrande L, Perrin M, Sapp JH 2nd, Wu D, Campolucci S, Walker DJ, Cone J, Pulliam P, Thalji L, Farfel MR, Thomas P (2006) Surveillance for World Trade Center heath effects among survivors of collapsed and damaged buildings. MMWR Surveill Summ 55:1–18
4. Banauch GI, Dhala A, Prezant DJ (2005) Pulmonary dsease in rescue workers at the World Trade Center site. Curr Opin Pulm Med 11:160–168
5. McGee JK, Chen LC, Cohen MD, Chee GR, Prophete CM, Haykal-Coates N, Wasson SJ, Conner TL, Costa DL, Gavett SH (2003) Chemical analysis of World Trade Center fine particulate matter for use in toxicologic assessment. Environ Health Perspect 111:972–980
6. Gil L, Martinez V, Riquelme R, Ancic P, Gonzalez G, Rodriguez L, Adonis M (2003) Occupational and environmental levels of mutagenic PAHs and respirable particulate matter associated with diesel exhaust in Santiago, Chile. J Occup Environ Med 45:984–992
7. Edelman P, Osterloh J, Pirkle J, Caudill SP, Grainger J, Jones R, Blount B, Calafat A, Turner W, Feldman D, baron S, Bernard B, Lushniak BD, Kelly K, Prezant D (2003) Biomonitoring of chemical exposure among New York City firefighters responding to the World Trade Center fire and collapse. Environ Health Perspect 111:1906–1911
8. Prezant DJ, Weiden M, Banauch GI, McGuiness G, Rom WN, Aldrich TK, Kelly KJ (2002) Cough and bronchial responsiveness in firefighters at the World Trade Center site. N Engl J Med 347:806–815
9. Kelly KJ, Niles J, McLaughlin MT, Carroll S, Corrigan M, Al-Othman F and Prezant DJ (2007) FDNY WTC Health Effects – a six year assessment, Fire Department of the City of New York, September 11, 2007
10. Herbert R, Moline J, Skloot G, Metzger K, Baron S, Luft B, Markowitz S, Udasin I, Harrison D, Stein D, Todd A, Enright P, Stellman JM, landrigan PJ, Levin SM (2006) The World Trade Center disaster and health of workers; five year assessment of a unique medical screening program. Environ Health Perspect 114:1853–1858
11. Toren K, Brisman J, Hagberg S, Karlsson G (1996) Improved nasal clearance among pulp-mill workers after the reduction of lime dust. Scand J Work Environ Health 22:102–107
12. Fireman EM, Lerman Y, Ganor E, Greif J, Fireman-Shoresh S, Lioy PJ, Banauch GI, Weiden M, Kelly KJ, Prezant DJ (2004) Induced sputum assessment in New York City firefighters exposed to World Trade Center dust. Environ Health Perspect 112: 1564–1569
13. Centers for Disease Control, Prevention (2002) Injuries and illnesses among New York City Fire Department rescue workers after responding to the World Trade Center attacks. MMWR Morb Mortal Wkly Rep 51:1–5
14. Centers for Disease Control, Prevention (2002) Rapid assessment of injuries among survivors of the terrorist attack on the World Trade Center—New York City, September 2001. MMWR Morb Mortal Wkly Rep 51:1–5
15. Berríos-Torres SI, Greenko JA, Phillips M, Miller JR, Treadwell T, Ikeda RM (2003) World Trade Center rescue worker injury and illness surveillance, New York, 2001. Am J Prev Med 25:79–87
16. Centers for Disease Control, Prevention. (2004) Physical Health status of World Trade Center rescue and recovery workers and volunteers – New York City, July 2002–August 2004. MMWR Morb Mortal Wkly Rep. 53:807–812
17. Salzman SH, Moosavy FM, Miskoff JA, Friedman P, Fried G, Rosen MJ (2004) Early respiratory abnormalities in emergency services police officers at the World Trade Center site. J Occup Environ Med 46:113–122
18. Buyantseva LV, Tulchinsky M, Kapalka GM, Chinchilli VM, Qian Z, Gillio R, Roberts A, Bascom R (2007) Evolution of lower respiratory symptoms in New York police officers after 9/11: a prospective longitudinal study. J Occup Environ Med 49: 310–317
19. Skloot G, Goldman M, Fischler D, Goldman C, Schechter C, Levin S, Teirstein A (2004) Respiratory symptoms and physiologic assessment of ironworkers at the World Trade Center disaster site. Chest 25:1248–1255
20. Tapp LC, Baron S, Bernard B, Driscoll R, Mueller C, Wallingford K (2005) Physical and mental health symptoms among NYC transit workers seven and one half months after the WTC attacks. Am J Ind Med 47:475–483
21. Herbstman JB, Frank R, Schwab M, Williams DL, Samet JM, Breysse PN, Geyh AS (2005) Respiratory effects of inhalation exposure among workers during the clean-up effort at the WTC disaster site. Environ Res 99:85–92
22. Centers for Disease Control, Prevention (2002) Self-reported increase in asthma severity after the September 11 attacks on the World Trade Center—Manhattan, New York, 2001. MMWR Morb Mortal Wkly Rep 51:781–784
23. Reibman J, Lin S, Hwang S, Gulati M, Bowers JA, Rogers L, Berger KI, Hoerning A, Gomez M, Fitzgerald EF (2005) The World Trade Center residents' respiratory health study: new onset respiratory symptoms and pulmonary function. Environ Health Perspect 113:406–411
24. Szema AM, Khedkar M, Maloney PF, Takach PA, Nickels MS, Patel H, Modugno F, Tso AY, Lin DH (2004) Clinical deterioration in pediatric asthmatic patients after September 11, 2001. J Allergy Clin Immunol 113:420–426
25. Pratter MR, Brightling CE, Boulet LP, Irwin RS (2006) An empiric integrative approach to the management of cough: ACCP evidence-based clinical practice guidelines. Chest 129(1 Suppl): 222S–231S
26. Friedman S, Cone J, Eros-Sarnyai M, Prezant D, Szeinuk J, Clark N, Milek D, Levin S, Gillio R (2006) Clinical guidelines for adults exposed to World Trade Center Disaster (Respiratory and Mental Health). City Health Information, NYC Department of Health and Mental Hygiene, September 2006
27. Banauch GI, Alleyne D, Sanchez R, Oldender K, Cohen HW, Weiden M, Kelly KJ, Prezant DJ (2003) Persistent bronchial hyperreactivity in New York City firefighters and rescue workers following collapse of World Trade Center. Am J Respir Crit Care Med 168:54–62
28. Feldman DM, Baron S, Mueller CA, Bernard BP, Lushniak BD, Banauch GI, Arcentales N, Kelly KJ, Prezant DJ (2004) Symptoms, respirator use, and pulmonary function changes among

New York City firefighters responding to the World Trade Center (WTC) disaster. Chest 125:1256–1264
29. Banauch GI, Dhala A, Alleyne D, Alva R, Santhyadka G, Krasko A, Weiden M, Kelly KJ, Prezant DJ (2005) Bronchial hyperreactivity and other inhalation lung injuries in rescue/recovery workers after the World Trade Center collapse. Crit Care Med 33:S102–S106
30. Banauch GI, Dhala A, Prezant DJ (2005) Pulmonary disease in rescue workers at the World Trade Center site. Curr Opin Pulm Med 11:160–168
31. Banauch GI, Hall C, Weiden M, Cohen HW, Aldreich TK, Christodoulou V, Arcentales N, Kelly KJ, Prezant DJ (2006) Pulmonary function after exposure to the World Trade Center collapse in the New York City Fire Department. Am J Respir Crit Care Med 174:312–319
32. Brooks SM, Weiss MA, Bernstein IL (1985) Reactive airways dysfunction syndrome. Chest 88:376–384
33. American Thoracic Society (2000) Guidelines for methacholine and exercise challenge testing – 1999. Am J Respir Crit Care Med 161:309–329
34. Gavett S. Haykal-Coates N, Highfill J, Ledbetter AD, Chen LC, Cohen MD, Harkema JR, Wagner JG, Costa DL (2003) World Trade Center fine particulate matter causes respiratory tract hyperresponsiveness in mice. Environ Health Perspect 111:981–991
35. Wheeler K, McKelvey W, Thorpe L, Perrin M, Cone J, Kass D, Farfel M, Thomas P, and Brackbill R (2007) Asthma diagnosed after September 11, 2001 among rescue and recovery workers: findings from the World Trade Center registry. Environ Health Perspect 115:1584–1590
36. Reed CE (2006) The natural history of asthma. J Allergy Clin Immunol 118:543–548
37. Wagner VL, Radigan MS, Roohan PJ, Anarella JP, Gesten FC (2005) Asthma in Medicaid managed care enrollees residing in New York City: results from a post-World Trade Center disaster survey. J Urban Health 82:76–89
38. Izbicki G, Chavko R, Banauch GI, Weiden MD, Berger KI, Aldrich TK, Hall C, Kelly KJ, Prezant DJ (2007) World Trade Center "sarcoid-like" granulomatous pulmonary disease in New York City Fire Department rescue workers. Chest 131:1414–1423
39. Culver DA, Newman LS, Kavuru MS (2007) Gene–environment interactions in sarcoidosis: challenge and opportunity. Clin Dermatol 25:267–275
40. Prezant D, Dhala A, Goldstein A, Janus D, Ortiz F, Aldrich TK, Kelly KJ (1999) The incidence, prevalence and severity of sarcoidosis in New York City firefighters. Chest 116:1183–1193
41. Rom WN, Weiden M, Garcia R, Yie TA, Vathesatogkit P, Tse DB, McGuinness G, Roggli V, Prezant D (2002) Acute eosinophilic pneumonia in a New York City firefighter exposed to World Trade center dust. Am J Respir Crit Care Med 166:797–800
42. Mann JM, Sha KK, Kline G, Breuer FU, Miller A (2005) World Trade Center dyspnea: bronchioloitis obliterans with functional improvement: case report. Am J Ind Med 48:225–229
43. Safirstein BH, Klukowitcz A, Miller R, Teirstein A (2003) Granulomatous pneumonitis following exposure to the World Trade Center collapse. Chest 123:301–304
44. DePalma A (2006) Medical views of 9/11 dust shows big gaps. *The New York Times*, October 26, 2006, pp 1
45. Mulshine J, Sullivan D (2005) Lung cancer screening. New Engl J Med 352:2714–2720
46. Gwaltney JM Jr, Jones JG, Kennedy DW (1995) Medical management of sinusitis: educational goals and management guidelines. The International Conference on sinus Disease. Ann Otol Rhinol Laryngol Suppl 167:22–30
47. DeVault KR, Castell DO, American College of Gastroenterology (2005) Updated guidelines for the diagnosis and treatment of gastroesophageal reflux disease. Am J Gastroenterol 100:190–200
48. Irwin RS, Madison JM (2000) Diagnosis and treatment of chronic cough due to gastroesophageal reflux disease and postnasal drip syndrome. Pulm Pharmacol Ther 15:261–266
49. Bars MP, Banauch GI, Appel DW, Andreaci M, Mouren P, Kelly KJ, Prezant DJ (2006) "Tobacco Free with FDNY" – The New York City Fire Department World Trade Center Tobacco Cessation Study. Chest 129:979–987