# Chapter 17

# EVALUATING THE EFFECTS OF AIRBORNE HAZARDS: A CLINICAL PERSPECTIVE FROM THE WAR RELATED ILLNESS AND INJURY STUDY CENTER

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# INTRODUCTION

## Brief Overview of the War Related Illness and Injury Study Center

The War Related Illness and Injury Study Center (WRIISC) of the US Veterans Health Administration (VHA) was founded by Congressional Mandate in 2001 in the context of continued concerns about the etiology, pathophysiology, and prognosis of Gulf War illnesses. Two WRIISCs were initially established, with a third created in 2007. With a mission to promote research, education, clinical care, and risk communication related to deployment health issues, the WRIISC focuses on difficult-to-diagnose conditions in veterans of the US armed forces and their possible link to deployment-related experiences. Based in the VHA's Office of Public Health, the WRIISCs have an explicit role in surveillance of the population health of deployed veterans. The VHA providers throughout the country refer patients with difficult-to-diagnose conditions to one of the three WRIISCs located in

- East Orange, NJ;
- Palo Alto, CA; and
- Washington, DC.

Each center offers a similar multiday, comprehensive, multidisciplinary evaluation of exposure and health concerns, as well as previous workups. The WRIISC works with patients to create a roadmap for moving forward with the referring team of providers. Through prospective, active review of clinical activity, the WRIISC program identifies novel exposure concerns and health conditions for further investigation.

## Airborne Hazards Experience of the War Related Illness and Injury Study Center

One of the most frequent exposure concerns reported by Gulf War veterans seen at the WRIISCs in New Jersey and Washington, DC, was smoke from burning oil wells.[1] These concerns were explicitly addressed by New Jersey WRIISC clinicians in a comprehensive, lifetime exposure assessment for every patient with additional diagnostic evaluation recommended on a case-by-case basis. In 2004, New Jersey WRIISC clinicians began evaluating veterans deployed to Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) and gaining clinical experience with their health and exposure concerns. By January 2006, New Jersey WRIISC experience with the first 56 OEF/OIF veterans evaluated indicated that air quality was one of the most common exposure concerns. Ear, nose, and throat symptoms were among the most prevalent, although the small sample size precluded the detection of a definitive association between these two observations.[2] Review of a larger sample of New Jersey WRIISC patients ($n$ = 469) from 2006 to 2010 indicated that approximately 90% of veterans evaluated at the New Jersey WRIISC reported exposure to airborne hazards, including smoke from burn pits, sand/dust, and general air pollution. The same proportion reported somewhat or greater concern about these exposures. This was the most prevalent exposure concern in this clinical population.[3]

Given the near universality of concern about airborne hazards during deployment to OEF/OIF, the clinical team developed an approach to addressing both concern about the exposure and symptoms reported that might be associated with airborne hazards exposure.

# CLINICAL EVALUATION

## Clinical Approach to Airborne Hazards at the War Related Illness and Injury Study Center

The comprehensive clinical evaluation for all patients seen at the WRIISC was designed to assess as many organ systems, symptoms, and health concerns as possible during the 1- to 3-day stay in East Orange, NJ. This included an extensive set of intake questions—some as formal, validated questionnaires (such as the Patient Health Questionnaire-15) and others developed by WRIISC staff to ascertain responses specific to postdeployment veterans. In 2006, a newly revised self-report exposure measure created by one of the authors (R.F.T.) was added to the set of questions. This measure allowed veterans to indicate whether they believe themselves to have been exposed and whether they were concerned about the exposure. Further details of this measure and analysis of responses have already been published.[3] Veterans' responses to all questions in the intake packet are electronically scanned or manually entered into an electronic database through which WRIISC investigators may access under an approved protocol.

Each veteran seen at the WRIISC was given a thorough history and physical examination by either a primary care physician with an interest in postdeployment health issues or a nurse practitioner with additional specialized training in conducting these examinations. In addition, each veteran was given a neuropsychological screening battery and a psychological interview, as well as an evaluation by a social worker. An occupational medicine physician conducted an in-person exposure evaluation with each veteran. This involved taking a lifelong exposure history, conducting an

in-depth discussion of exposures during military service and deployment, and executing a discussion of all postmilitary exposures. Each exposure was explored with the veteran in regard to location, duration, intensity, and frequency of exposure; a strong emphasis was placed on eliciting a temporal correlation between exposure and the onset or worsening of health symptoms. All provider notes from this comprehensive evaluation are entered into the US Department of Veterans Affairs (VA) Computerized Patient Record System.

Sometime in late 2009, the WRIISC clinical staff noted that the portion of OEF/OIF veterans reporting respiratory symptoms was increasing. At the same time, review of these veterans' pulmonary function testing (PFT) conducted at their home VA Medical Centers revealed values within normal range, defined as forced expiratory volume in 1 second ($FEV_1$) and forced vital capacity, both equal to or above 80% of predicted (see section below for further discussion of this definition of "normal"). Several reports were published in 2009 and 2010 that proposed a correlation between OEF/OIF veterans' deployment airborne exposures and their respiratory symptoms.[4–6] Personal communications between one of the authors (R.F.T.) and several colleagues, both with the Department of Defense and the VA, indicated that there were veterans evaluated with normal PFTs who revealed significant bronchodilator response when tested.

In September 2011, an agreement was established with the Pulmonary Function Laboratory at the East Orange VA Medical Center and the WRIISC to enable each veteran (with or without respiratory symptoms) seen at the WRIISC to have a comprehensive PFT performed during their brief visit. This testing would include diffusion capacity and spirometric testing without and then subsequent to the administration of a bronchodilator medication. The remainder of this chapter discusses these preliminary findings of the first 20 consecutive WRIISC OEF/OIF veterans to undergo this testing. The PFT was performed as part of the clinical surveillance mission of the WRIISC and therefore did not require institutional review board approval. However, retrospective analysis of these data has received local institutional review board approval.

## Clinical Observations of 20 Operation Enduring Freedom/Operation Iraqi Freedom Veterans

We reviewed retrospectively medical records and intake questionnaire packets from OEF/OIF veterans who underwent clinical evaluations at the New Jersey WRIISC. Chest roentgenograms were already being obtained on all veterans seen who had not had this test within 1 to 2 years of their visit to the WRIISC. Overall, these roentgenograms were unremarkable. We selected the first 20 consecutive veterans who completed PFT as part of their comprehensive clinical evaluation—a process that started at the New Jersey WRIISC in the fall of 2011.

For the purposes of characterizing our clinical sample, we extracted key demographic variables, medical histories, and symptom reports from both the veterans' medical records and intake questionnaire packet responses. These data are presented individually for each veteran in Table 17-1. Variables were computed as follows:

- *Mental Health Diagnosis*—Provider diagnosis of posttraumatic stress disorder, panic disorder, and/or depression.
- *Respiratory Symptoms in Top Three*—Each veteran self-reports his/her top three symptoms of concern. For example, these may include widespread pain, balance or dizziness, and/or shortness of breath or coughing. These top three symptoms are part of the intake packet and often represent reasons why the veteran is seeking evaluation at the WRIISC.
- *Smoking Status*—Veterans were categorized as never, current, or past (>100 cigarettes/cigars/pipes in lifetime) smokers.
- *Lower Respiratory Symptoms*—Symptoms include coughing, bronchitis, wheezing, and/or dyspnea.
- *Upper Respiratory Symptoms*—Symptoms include sinusitis and/or rhinitis.
- *Abnormal Radiological Findings*—Abnormalities reported in the medical record may include abnormal findings on chest X-ray, computed tomography, and/or magnetic resonance imaging.

## Summary of Findings From Clinical Evaluation and Questionnaires

Our sample is predominantly young (40.4 ± 12.2 years), male (85%), white non-Hispanic (85%), and overweight/obese (with a body mass index of 31.02 ± 4.9). Most are Army veterans (80%), and 75% served in OIF. Three veterans had served in conflicts prior to 2001 (Persian Gulf, Kosovo, and Vietnam), and five veterans had served in OEF.

Mental health diagnoses were observed in all but five of these veterans, and 30% (6 of 20) were current smokers. Respiratory symptoms of lower (75%) and upper (55%) airways were present in most veterans; however, only 6 of 20 veterans (30%) listed respiratory symptoms in their top three symptom concerns. Four veterans had abnormal lung radiological findings.

All but two veterans endorsed exposure to airborne hazards during their exposure evaluation with an occupational medicine physician. Exposure medical notes were further reviewed in these 18 veterans to determine the frequency of *specific* airborne hazards concerns that were grouped into the following five categories:

**TABLE 17-1**

**DATA ABSTRACTED FROM THE COMPUTERIZED MEDICAL RECORD AND WRIISC DATABASE**

| ID | Age | Gender | BMI | Mental Health Diagnosis | Respiratory Symptoms | Smoking Status in Top 3 | Lower Respiratory Symptoms | Upper Respiratory Symptoms | Abnormal Radiological Findings |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 43 | Female | 25.23 | Y | N | Current | Y | Y | N |
| 2 | 42 | Male | 34.78 | N | Y | Never | Y | Y | N |
| 3 | 33 | Male | 27.73 | Y | N | Past | Y | Y | N |
| 4 | 64 | Male | 31.39 | Y | Y | Past | Y | N | Y |
| 5 | 29 | Female | 24.18 | Y | N | Past | Y | N | Y |
| 6 | 43 | Male | 32.56 | Y | Y | Never | N | Y | N |
| 7 | 51 | Male | 41.14 | Y | N | Current | N | Y | Y |
| 8 | 23 | Male | 33.64 | Y | N | Current | N | N | N |
| 9 | 64 | Male | 37.67 | Y | Y | Never | Y | Y | N |
| 10 | 56 | Male | 24.33 | Y | Y | Never | Y | Y | Y |
| 11 | 44 | Male | 29.49 | N | N | Never | Y | N | Y |
| 12 | 26 | Male | 29.35 | Y | N | Current | Y | Y | N |
| 13 | 26 | Female | 29.16 | N | N | Never | Y | Y | N |
| 14 | 41 | Male | 37.67 | Y | N | Never | Y | N | N |
| 15 | 38 | Male | 30.44 | N | N | Never | N | N | N |
| 16 | 29 | Male | 22.57 | Y | N | Current | Y | Y | N |
| 17 | 47 | Male | 35.05 | Y | N | Past | N | N | N |
| 18 | 25 | Male | 29.63 | Y | N | Never | Y | N | N |
| 19 | 38 | Male | 33.98 | Y | N | Current | Y | N | N |
| 20 | 46 | Male | 30.48 | N | Y | Past | Y | Y | N |

BMI: body mass index; DoD: Department of Defense; ID: identification; N: no; WRIISC: War Related Illness and Injury Study Center; VA: Veterans Affairs; Y: yes
Data source: VA/DoD Airborne Hazards Symposium, Arlington, Virginia, August 2012.

1. smoke from burning trash,
2. sand and/or dust,
3. regional air pollution,
4. fuels and/or chemicals, and
5. other (eg, cigarette smoke, mold, and asbestos).

The frequencies of specific airborne hazards concerns are shown in Figure 17-1. Note that the most common exposure was exposure to sandstorms and/or airborne dust (80%).

## Pulmonary Function Testing

The PFTs were conducted by a Registered Respiratory Therapist in the Department of Pulmonary and Critical Care Medicine at the VA New Jersey Health Care System (East Orange, NJ). Lung volumes and flows were obtained according to standardized guidelines[7] via body box and pneumotach, respectively. PFTs were performed in the morning in a fasted state by all veterans. Predicted values for our laboratory are based on the reference equations listed in Table 17-2.

Data are presented individually for each veteran in Table 17-3 and expressed as a percentage of their predicted values.

## Summary of Findings From Pulmonary Function Testing

We used the simplified algorithm provided by the American Thoracic Society and the European Respiratory Society (see Pelligrino et al,[7] Figure 2) to assess lung function in

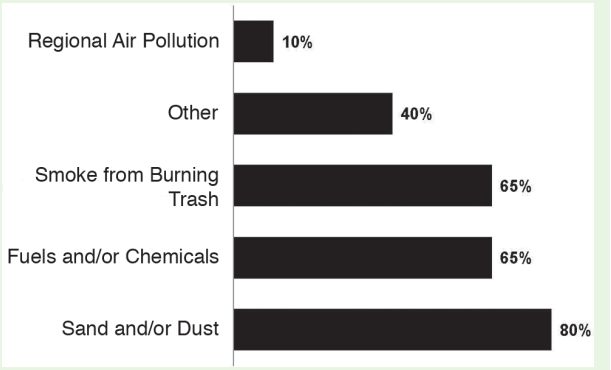


**Figure 17-1**. Frequency of specific airborne hazards exposure in 18 veterans. "Other" refers to cigarette smoke, mold, and asbestos.

this sample. Using these classic patterns, we observed four veterans with abnormal patterns (patient no. 4 = restriction; patient nos. 16, 17, and 20 = obstruction). Therefore, the majority of the sample performed within normal ranges. However, there was a considerable range in our measured variables, with some veterans producing values close to the lower limit of normal (LLN). For example, one in four veterans had $FEV_1$ values that were lower than the LLN. Means and standard deviations for each of these variables are provided in Table 17-4.

## SUMMARY

Prior work from the New Jersey WRIISC has shown that veterans of Afghanistan and Iraq are concerned about their deployment-related exposures,[2,3] and these concerns are associated with their somatic symptom burden.[3] This concern seems justified because prior reports have indicated that the deployment environment of OEF/OIF contains high levels of particulate matter that exceed environmental, occupational, and military exposure guidelines.[6,8] In fact, exposure to these particulates—especially those that are combustion-derived—may induce pulmonary inflammation that is associated with the pathogenesis and exacerbation of airway diseases.[9,10] The military population also warrants additional attention given the physically active nature of their service which, like exercise, necessitates an increase in pulmonary ventilation and diffusion capacity. Therefore, if service members are physically active in a location with high-ambient particulate matter, the lung concentration of inhaled particulates will increase. This has been demonstrated experimentally because the total amount of particulate matter deposited in the lungs is 4.5-fold higher during exercise than at rest, thereby making deposition of particles a function of minute ventilation.[11] This significant increase in particle deposition during exercise may also be related to a greater increase in oral rather than nasal breathing as the intensity of physical activity increases, thereby bypassing protective filtering functions of the nasopharyngeal region. These experimental data may support the reports of new-onset respiratory conditions in OEF/OIF veterans[4,12,13] and reports of exercise intolerance.[14]

Several features of the military environment are favorable for the development of respiratory illnesses that include close living quarters, unique stressors, and barracks with closed ventilation systems. Therefore, respiratory infections during deployment to OEF/OIF have been commonly reported. Thus, the incidence of self-reported respiratory illness has been estimated between 40% to 70% during deployment to Afghanistan or Iraq.[12,13] Although these rates have appeared to decline from the early stages of the conflict (ie, 69% vs 40%), the question remains whether respiratory symptoms persist postdeployment, and whether these symptoms and illnesses precede the development of respiratory disease. Few experimental studies are available to determine whether exposure to airborne hazards during deployment negatively impacts lung function postdeployment. To this end, the WRIISC has introduced standardized pulmonary evaluations for all veterans who participate in our clinical evaluation. Herein, we present our preliminary findings from the first 20 consecutive OEF/OIF veterans who performed PFTs as part of their evaluation.

The overwhelming majority of OEF/OIF veterans clinically evaluated at the WRIISC endorsed exposure to airborne hazards during their deployment (90%), as well as lower airway respiratory symptoms (75%), such as coughing, wheezing, and shortness of breath. It remains unclear whether symptoms are attributable to these exposures; however, it is concerning that symptoms are maintained several years following their deployment to OEF/OIF (5.4 ± 2.6 years = date of WRIISC visit – date of separation). Despite the frequency of symptoms, only 30% of our sample indicated respiratory symptoms as one of their top three reasons for coming to the WRIISC.

**TABLE 17-2**

**REFERENCE EQUATIONS FOR PULMONARY FUNCTION TESTING**

| Pulmonary Function Testing Variables | Reference Equations |
|---|---|
| Lung volumes | |
| Total lung capacity | Crapo, 1982 |
| Vital capacity | Crapo, 1981 |
| Forced residual capacity | Boren and Korey, 1966 |
| Residual volume | Boren and Korey, 1966 |
| Spirometry | |
| Forced vital capacity | Crapo, 1981 |
| Forced expiratory volume in 1 second | Morris, 1985 |
| Forced expiratory flow between 25%–75% of vital capacity (FMEF 25%–75%) | Crapo, 1981 |

FMEF: forced midexpiratory flow

Data sources: Crapo RO, Morris AH, Clayton PD, Nixon CR. Lung volumes in healthy nonsmoking Adults. *Bull Eur Physiopathol Respir.* 1982;18:419–425. Crapo RO, Morris AH, Gardner RM. Reference spirometric values using techniques and equipment that meet ATS recommendations. *Am Rev Respir Dis.* 1981;123:659–664. Boren HG, Kory RC, Syner JC. The Veterans Administration Army Cooperative Study of Pulmonary Function. II. The lung volume and its subdivisions in normal men. *Am J Med*. 1966;41:96–114. Morris J, Temple W. Spirometric "lung age" estimation for motivating smoking cessation. *Prev Med*. 1985;14:655–662.

**TABLE 17-3**

**LUNG VOLUME AND SPIROMETRY DATA**

| ID | TLC (%) | VC (%) | FRC (%) | RV (%) | FVC (%) | $FEV_1$ (%) | FMEF (25%–75%) | $FEV_1$/FVC |
|---|---|---|---|---|---|---|---|---|
| 1 | 106.54 | 125.61 | 129.04 | 61.58 | 125.61 | 111.22 | 83.92 | 0.73 |
| 2 | 85.74 | 86.72 | 95.13 | 75.38 | 86.72 | 80.69 | 65.42 | 0.76 |
| 3 | 95.23 | 102.00 | 120.85 | 63.16 | 97.41 | 98.56 | 99.95 | 0.84 |
| 4 | 64.91 | 51.84 | 50.86 | 89.02 | 50.71 | 56.81 | 100.23 | 0.86 |
| 5 | 91.28 | 97.66 | 75.00 | 67.86 | 97.66 | 99.39 | 108.25 | 0.87 |
| 6 | 81.45 | 78.79 | 103.75 | 81.22 | 78.79 | 72.39 | 54.25 | 0.75 |
| 7 | 93.23 | 103.28 | 82.42 | 64.25 | 99.78 | 100.00 | 105.05 | 0.81 |
| 8 | 73.26 | 95.12 | 93.09 | 75.63 | 95.12 | 90.67 | 82.69 | 0.79 |
| 9 | 75.78 | 89.02 | 87.65 | 48.48 | 89.02 | 94.83 | 136.78 | 0.84 |
| 10 | 90.93 | 102.15 | 169.42 | 62.61 | 102.15 | 91.52 | 59.15 | 0.70 |
| 11 | 92.24 | 92.01 | 93.47 | 85.51 | 92.01 | 93.50 | 104.48 | 0.81 |
| 12 | 81.17 | 87.84 | 108.36 | 48.62 | 85.64 | 78.56 | 62.70 | 0.75 |
| 13 | 99.13 | 100.87 | 114.22 | 93.91 | 100.87 | 88.56 | 63.33 | 0.78 |
| 14 | 99.72 | 107.66 | 110.39 | 69.50 | 107.66 | 103.32 | 96.26 | 0.78 |
| 15 | 87.86 | 86.93 | 101.37 | 82.09 | 86.93 | 85.62 | 81.67 | 0.80 |
| 16 | 106.82 | 110.37 | 198.04 | 80.92 | 110.37 | 83.18 | 47.66 | 0.62 |
| 17 | 25.80 | 108.92 | 128.96 | 128.00 | 107.22 | 88.71 | 54.01 | 0.67 |
| 18 | 85.05 | 88.43 | 78.35 | 62.07 | 87.74 | 80.50 | 69.39 | 0.76 |
| 19 | 86.49 | 94.01 | 83.51 | 58.21 | 94.01 | 91.69 | 90.72 | 0.79 |
| 20 | 96.55 | 108.75 | 98.55 | 59.62 | 108.15 | 69.63 | 27.67 | 0.52 |

$FEV_1$: forced expiratory volume in 1 second; FMEF: forced midexpiratory flow; FRC: forced residual capacity; FVC: forced vital capacity; ID: identification; %: percent of predicted value; RV: residual volume; TLC: total lung capacity; VC: vital capacity

Lung volume and spirometry data were primarily normal, with the exception of four veterans who demonstrated obstructive patterns. In addition, approximately 25% of our sample had $FEV_1$ values that were lower than the LLN. Given the absence of prior PFT data (ie, predeployment or pre-WRIISC visit), our assessment provides only a snapshot of lung function. Serial PFTs would afford a better assessment of lung function over time and that may facilitate a better understanding of whether deployment-related exposures and/or smoking may affect lung function.

To address the limitations of single timepoint spirometry and lung volume testing, the New Jersey WRIISC has implemented and is considering additional testing, such as reversibility testing with a bronchodilator, lung-diffusing capacity, and cardiopulmonary exercise testing. These additional tests may provide a more comprehensive evaluation of integrated lung function, and we hope to make these data available to the community in the near future. We also want to highlight that data presented herein are mostly descriptive and preliminary in nature. Therefore, one should exercise caution in extrapolating these data until further cases are evaluated and more detailed studies are performed.

There are several key issues that warrant attention from the clinical and research communities. First, the challenges of assessing exposures during deployment are substantial,[15] and previous research has demonstrated the difficulties regarding misclassifying exposures for determining associations between potential exposures and adverse health outcomes.[16] At the WRIISC, detailed exposure histories are conducted by occupational medicine physicians with veterans. There is widespread agreement that these histories are subject to recall bias, and the population of veterans seen at the WRIISC is subject to (self-) selection bias. Because

**TABLE 17-4**

**AVERAGE VALUES FOR SELECTED PULMONARY FUNCTION TESTING VARIABLES**

| PFT Variables | Mean ± SD |
|---|---|
| TLC | 86.0% ± 17.7% |
| VC | 95.9% ± 15.1% |
| FRC | 106.1% ± 32.9% |
| RV | 72.9% ± 18.2% |
| FVC | 95.2% ± 15.1% |
| $FEV_1$ | 88.0% ± 12.7% |
| FMEF (25%–75%) | 79.7% ± 26.1% |

$FEV_1$: forced expiratory volume in 1 second; FMEF: forced midexpiratory flow; FRC: forced residual capacity; FVC: forced vital capacity; PFT: pulmonary function testing; RV: residual volume; SD: standard deviation; TLC: total lung capacity; VC: vital capacity

a one-on-one interview is not feasible for all veterans, we must develop appropriate metrics through which to quantify exposure. Second, we currently lack a well-accepted clinical protocol on how to approach the OEF/OIF veteran who may present with respiratory symptoms or limitations. Our approach must have a favorable risk-to-benefit ratio and provide appropriate sensitivity to improve the differential diagnosis. Lastly, we emphasize that the extent and severity of deployment-related lung injury remain unclear. Therefore, additional studies are greatly needed to better understand the scope of this problem, if any, and how best to treat affected veterans.

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