Overview and Recommendations for Medical Screening and Diagnostic Evaluation for Postdeployment Lung Disease in Returning US Warfighters

Cecile Rose, MD, MPH, Joseph Abraham, ScD, MS, Deanna Harkins, MD, MPH, Robert Miller, MD, Michael Morris, MD, Lisa Zacher, MD, Richard Meehan, MD, Anthony Szema, MD, James Tolle, MD, Matthew King, MD, David Jackson, PhD, John Lewis, PhD, Andrea Stahl, PhD, Mark B. Lyles, DMD, PhD, Michael Hodgson, MD, MPH, Ronald Teichman, MD, MPH, Walid Salihi, DO, Gregory Matwiyoff, MD, Gregory Meeker, MS, Suzette Mormon, MPH, RN, Kathryn Bird, MD, MSPH, and Coleen Baird, MD, MPH

Objective: To review inhalational exposures and respiratory disease risks in US military personnel deployed to Iraq and Afghanistan and to develop consensus recommendations for medical screening and diagnostic referral. **Methods:** A Working Group of physicians and exposure scientists from academia and from the Departments of Defense and Veterans Affairs was convened in February 2010. **Results:** Despite uncertainty about the number of people affected and risk factors for adverse pulmonary outcomes in this occupational setting, the Working Group recommended: (1) standardized approaches to pre- and postdeployment medical surveillance; (2) criteria for medical referral and diagnosis; and (3) case definitions for major deployment-related lung diseases. **Conclusions:** There is a need for targeted, practical medical surveillance for lung diseases and for a standardized diagnostic approach for all symptomatic deployed personnel.

Learning Objectives

- Become familiar with published data on inhalational exposures and respiratory disease risks in U.S. military personnel deployed to Iraq and Afghanistan, as reviewed by the Working Group.
- Summarize the Working Group's recommendations on standardized pre- and post-deployment medical surveillance, criteria for medical referral and diagnosis, and case definitions for deployment-related lung diseases.
- Identify areas of disagreement with the Working Group recommendations in the accompanying "clarification" by the Department of Defense.

In the last few years, evidence has emerged that US military personnel deployed to Iraq and Afghanistan may be at risk for developing respiratory symptoms and, in some cases, disabling chronic lung diseases including asthma and constrictive bronchiolitis (CB). Although no specific risk factors other than "deployment to southwest Asia" have been definitively linked to these health outcomes, concerns have been raised about exposures to various airborne contaminants.[1] Specific inhalation exposures of concern include emissions from open-air burn pits, desert dust particulate matter (PM), industrial fires and emissions, and vehicular exhaust.

From the Department of Medicine (Drs Rose, Meehan, and Bird), National Jewish Health and University of Colorado Denver; US Army Public Health Command (Drs Abraham, Harkins, and Baird), Aberdeen Proving Ground, Md; Vanderbilt University School of Medicine (Drs Miller, Tolle, and King), Nashville, Tenn; Department of Medicine (Drs Morris and Zacher), Brooke Army Medical Center, Ft Sam Houston, Tex; SUNY Stony Brook School of Medicine (Drs Szema and Salihi), Stony Brook, and Veterans Affairs Medical Center, Northport, NY; US Army Center for Environmental Health Research (Drs Jackson, Lewis, and Stahl), Ft Detrick, Md; US Naval War College (Dr Lyles), Washington, DC; Occupational Health, Office of Public Health (Dr Hodgson), VHA, Department of Veterans Affairs, Washington, DC; War Related Illness and Injury Study Center (Dr Teichman), VA New Jersey Health Care System, Department of Veterans Affairs, East Orange, NJ; Navy Medical Center (Dr Matwiyoff), San Diego, Calif; and US Geological Survey (Mr Meeker and Ms Mormon), Denver, Colo.

Author Rose received a Department of Defense grant in 2011; she receives royalties from a contribution to a chapter in an online journal on silicosis. She and her coauthors have no relationships/conditions/circumstances that present potential conflict of interest.

The JOEM Editorial Board and Planners have no financial interest related to this research.

The opinions expressed herein represent those of the authors and do not represent those of the Department of Veterans Affairs or the Department of Defense.

Address correspondence to: Cecile Rose, MD, MPH, National Jewish Health, 1400 Jackson St, Denver, CO 80206 mail to: rosec@njhealth.org

DOI: 10.1097/JOM.0b013e31825297ba

Prompted by these concerns, a Working Group of pulmonologists, occupational and preventive medicine specialists, industrial hygienists, and exposure scientists from several academic medical centers, the Department of Defense (DoD), and the Department of Veterans Affairs was convened in February 2010.[2] These physicians and scientists, six of whom had previously deployed to southwest Asia, reviewed known and potential respiratory health outcomes and information about potential risk factors. The Working Group discussed the exposure parameters that might confer increased risk for postdeployment lung disease such as the type, severity, and duration of exposure, deployment for extended periods or multiple times, proximity and duration of exposure to burn pits or fires, reported frequency of exposure to desert dust storms, and particular job duties. The Working Group noted that factors such as general climactic conditions (heat and humidity) as well as individual factors (ie, smoking status, body mass index) in addition to deployment exposures may contribute to respiratory disease risk. Given potential adverse pulmonary outcomes, the Working Group recommended: (1) standardized pre- and postdeployment medical surveillance approaches (Table 1); (2) criteria for medical referral and diagnosis; and (3) case definitions for key deployment-related lung diseases. These recommendations along with a summary of major respiratory exposure hazards, lung diseases of concern, and future needs and directions are described in this article.

EPIDEMIOLOGY

Since 2001, approximately two million US military personnel have deployed to Iraq or Afghanistan in support of Operation Iraqi Freedom (OIF) or Operation Enduring Freedom (OEF), respectively. Reports of increased acute respiratory illnesses in deployed troops began surfacing in 2004, when a survey of 15,000 troops deployed to southwest Asia found that 69.1% reported respiratory illnesses, with 17% requiring medical care while deployed, a doubling of precombat

TABLE 1. Recommended Components of Pre- and Postdeployment Medical Surveillance

Standardized questionnaire eliciting
Smoking history
Pertinent medical history
Respiratory symptoms
Spirometry (before and after bronchodilator)
Exercise capacity evaluation (Physical Readiness Test) including 1- or 2-mile run times

lung conditions.[3] Subsequent investigations showed that deployers (defined as those remaining in country for at least 30 days) have higher rates of newly reported respiratory symptoms than nondeployers (14% vs 10%), though rates of physician-diagnosed asthma and chronic bronchitis were not increased.[4] Deployment was associated with increased reports of respiratory symptoms in both Army and Marine Corps personnel, independent of smoking status. Furthermore, a linear dose–response relation between length of deployment and respiratory symptoms was found for Army but not for Marine, Air Force, or Navy personnel, suggesting different exposure risk for land-based service members.[4] Recent investigations suggest that obstructive airways diseases, including asthma and CB, are occurring in excess in returning troops.[5,6] As US military personnel continue to experience multiple and prolonged deployments to these regions, concerns about exposure-related respiratory sequelae are likely to intensify.

INHALATIONAL EXPOSURES

Efforts to characterize air, water, and soil exposures in deployment environments in Iraq and Afghanistan have been undertaken by the DoD since 2003. Attention has focused on exposures to burn pits operating in close proximity to where troops live and work, to industrial emissions, and to PM from ambient desert dust. The following sections briefly summarize current knowledge in each of these three exposure settings.

Exposure to Burn Pits

Recent media and congressional attention has focused on the potential for lung injury and other illnesses from exposure to burn pit operations. According to DoD estimates, in a typical military operation, each American soldier generates 9 to 12 lb of waste a day. That waste must be burned in pits or incinerators. The open burning of solid and chemical wastes has been practiced in areas of southwest Asia where military personnel are stationed, particularly in the early years of both conflicts. Although regulations exist for segregating waste,[7] testimony provided in congressional hearings describes deviations from recommended policies, with reports of burn pits containing mixtures of rubber, plastic, metals, electronics, paints, solvents, petroleum, wood, and unexploded ordnance and munitions. Jet fuel (JP-8) has been used to start the combustion process. Open burn pits and simple incinerators with limited pollution controls generate smoke plumes with poorly characterized and highly variable constituents. Changing environmental conditions may cause the smoke plume from a burn pit to change direction or fall toward the ground where people live and work.

Accurate information about the number of burn pits is difficult to come by. An April 2010 source[8] described 50 open-air burn pits in operation in Iraq and another 34 in Afghanistan. According to a recent Institute of Medicine report,[9] the use of burn pits in Iraq was gradually phased out by 2009, but 197 burn pits were operating in Afghanistan as of January 2011. Particular attention has focused on burn pit smoke at Joint Base Balad (JBB) in Iraq, an approximately 10-acre area containing burning piles of trash that generated respiratory complaints and health concerns dating back to 2003. Samples collected at JBB by the US Army Center for Health Promotion and Preventive Medicine from January to April 2007 showed high $PM_{2.5}$ levels, averaging 56 $\mu g/m^3/d$ (exceeding the 1-year air Military Exposure Guidelines maximum of 15 $\mu g/m^3/d$). Airborne levels at JBB did not exceed Military Exposure Guidelines recommendations for exposure to metals, volatile organic compounds, dioxins, furans, or polycyclic aromatic compounds. The Defense Health Board, an independent board of academic and private experts, concluded on the basis of the analytes measured that "no significant short- or long-term health risks and no elevated cancer risk are likely among personnel deployed to Balad Air Base /JBB." Continuing concerns about risks from burn pit exposures have spurred recent construction of incinerators as replacements for waste handling in some areas where troops are deployed, including JBB where a large burn pit was closed in October 2009 and replaced by three closed incinerators.

Exposure to Industrial Fires

Although smoke from burning oil wells was a substantially greater concern during the Operations Desert Shield/Desert Storm[10] than in the current southwest Asia theatre of operations, exposure to smoke from other types of fires has been a problem in certain areas. A fire that accidentally ignited at the Mishraq State Sulfur Mine plant in Mosul, Iraq in June 2003 burned for 3 weeks and released a sustained plume of smoke over a geographic area extending 25 km to the south and 50 km north to the Mosul Airfield. The plume contained variable but frequently high quantities of PM, H_2S, and SO_2.[11] Troops likely to have been most exposed were nearly 200 firefighters (primarily from the 101st Airborne Division) and support personnel (including medics) assigned to fight the fire, with inadequate personal protective equipment for the high levels of SO_2 and H_2S present. United States Army Public Health Command estimates that more than 6000 returning troops (based on unit location) may have been exposed to the sulfur fire plume.

Exposure to PM From Desert Dust Storms and Other Sources

Crustal dust and sand storms, sometimes lasting for days and often intense enough to obscure visibility, are a recurring problem in the Middle East and add substantially to the airborne PM levels facing deployed troops. Such storms occur for 20 to 50 days per year, most commonly in spring and summer months. In addition to desert dust, a Rand report funded by the US Army described widespread degradation of soils in developing countries related to overuse by heavy industry, use of leaded gasoline, and lack of environmental controls.[12]

In 2005, the Joint Particulate Matter Working Group convened a symposium at the National Institute for Occupational Safety and Health to review sampling results, potential health effects, and future directions. Given findings of high PM exposure in both Iraq and Afghanistan, recommendations were made for more complete PM sampling and exposure characterization. The military's Enhanced Particulate Matter Surveillance Program has since collected more than 3000 filter samples along with bulk dust and soil samples from 15 Middle East deployment sites, including two in Afghanistan (Bagram and Khowst) and six in Iraq (Balad, Baghdad, Tallil, Tikrit, Taji, and Al Asad).[13] All sites exceeded the US Army Center for Health Promotion and Preventive Medicine 1-year Military Exposure Guidelines value of 15 $\mu g/m^3$ for $PM_{2.5}$, the fraction in which trace-metal concentrations of lead, arsenic, cadmium, antimony, and zinc were concentrated. The three main air pollutions sources were geological dust, smoke from burn pits, and lead-zinc smelter and battery-processing facilities.

RESPIRATORY DISEASES OF CONCERN

Although data about the long-term effects of complex and variable deployment inhalational exposures are limited, there is

emerging evidence to suggest that deployment may be associated with an increase in risk for asthma (both new onset asthma and aggravation of preexisting asthma), CB, and acute eosinophilic pneumonia (AEP).

Asthma

There is abundant medical literature showing a relationship between exposure to airborne particulates and risk for airways disease. Besides mucus membrane and eye irritation symptoms, asthma can occur after acute exposure to high concentrations of substances (including particulate combustion products) with known respiratory irritant properties.[14] In recently reported data from the World Trade Center disaster exposure registry, researchers[15] found that 19% of rescue/recovery workers with intense exposure reported a new diagnosis of asthma, compared with 9.6% in those without exposure.

Since 2004, an established diagnosis of asthma (based on symptoms, medication use, and spirometric testing) after the age of 12 years has been an exclusion criterion for enlistment in the US military unless the individual applies for and obtains a waiver. Five percent of troops deployed to southwest Asia reported a previous diagnosis of asthma.[16] Both asthmatic and nonasthmatic deployers reported statistically significantly increased respiratory symptoms during deployment compared with symptoms preceding deployment. Extreme climate conditions including wide ambient temperature variations and low humidity, along with high PM exposures, probably contributed to poor asthma control and to new onset asthma in deployers. A retrospective review[6] of asthma diagnoses in more than 6000 medical records from Veterans Affairs patients found significantly higher rates of asthma (based on *International Classification of Diseases–Ninth Revision* diagnostic codes) in US military personnel stratified by age and sex who were deployed to Iraq between 2004 and 2007 compared with military personnel stationed in the United States (6.6% vs 4.3%; $P = 0.003$; odds ratio, 1.58; 95% confidence interval, 1.18 to 2.11). Concurrent rhinitis was also more likely to be diagnosed in the Iraq-deployed cohort. More sensitive measures such as pre- and postbronchodilator spirometry, methacholine challenge, impulse oscillometry to assess small airways, and exhaled breath condensate nitric oxide levels will be clinically important in assessing possible asthma in returning US military personnel.

Constrictive Bronchiolitis

Constrictive bronchiolitis, sometimes used interchangeably with the histologic term bronchiolitis obliterans, is a lung disease characterized by fixed airways obstruction and fibrosis of the distal airways or bronchioles, with extrinsic narrowing (CB) or obliteration (bronchiolitis obliterans) of the bronchiolar lumen. Known causes of bronchiolitis include certain inhalational exposures (ie, nitrogen and sulfur oxides and components of butter flavoring), infections, connective tissue diseases, and drugs as well as heart and lung transplantion.[17,18]

The clinical manifestations of bronchiolitis are nonspecific, and disease is difficult to distinguish from more common obstructive lung diseases such as chronic asthma and emphysema. Constrictive bronchiolitis usually presents with subtle onset of exertional shortness of breath and nonproductive cough. Pulmonary function tests (PFTs) typically show airflow obstruction that does not improve with bronchodilator, though resting pulmonary function may be normal, particularly in early small airways disease. Static lung volumes show hyperinflation; diffusion capacity for carbon monoxide is usually normal. Pulmonary function tests are often helpful in diagnosis and for assessing disease severity. Chest radiograph is usually normal but may show hyperinflation or bronchial wall thickening. High-resolution computed tomography (HRCT) of the chest often shows heterogeneous (mosaic) air trapping most prominent on expiratory imaging, sometimes with areas of patchy ground-glass opacities and scattered cylindrical bronchiectasis.[19] Findings of bronchial wall thickening and centrilobular nodules may make CB difficult to distinguish from severe asthma. Surgical lung biopsy shows both external constriction and peribronchiolar fibrosis of terminal and respiratory bronchioles, best seen using elastic stains. The histopathologic lesions of CB may be minimal and patchy and generally require an experienced pulmonary pathologist, and the findings on surgical lung biopsy must be informed by other clinical findings including symptoms, smoking, or occupational exposure histories.[20]

Between 2005 and 2009, 80 soldiers returning from southwest Asia to Fort Campbell, Kentucky, were referred to a major academic medical center for evaluation of postdeployment respiratory symptoms.[5] The typical affected soldier complained of shortness of breath on exertion and an inability to complete a 2-mile run without stopping. In most cases, PFTs and chest HRCT were normal or only mildly abnormal. Of the 80 symptomatic soldiers, 49 were referred for surgical lung biopsy. Of these, 38 had biopsy findings of CB, of whom two thirds (25 of 38) were never smokers. Although the majority of affected soldiers reported exposure to the 2003 Mishraq sulfur fire, 10 of 38 with biopsy-confirmed CB reported only the usual exposures such as battlefield smoke, dust storms, diesel exhaust, and burn pits.

Acute Eosinophilic Pneumonia

Acute eosinophilic pneumonia is a rare, idiopathic lung disease characterized by acute onset of fever and respiratory symptoms accompanied by infiltrates on chest imaging, and eosinophilia in bronchoalveolar lavage and/or lung biopsy. In 2004, 18 cases of AEP (including two fatalities) were reported among 183,000 military personnel deployed in or near Iraq between March 2003 and March 2004.[21] Epidemiologic investigation showed no evidence of a common source exposure, temporal or geographic clustering of cases, association with recent vaccination, or person-to-person transmission. All of the affected cases were cigarette smokers, with 78% reporting recent onset of smoking. All but one reported significant exposure to fine airborne sand and dust during deployment. The authors suggest that "recent exposure to tobacco may prime the lung in some way such that a second exposure or injury, eg, in the form of dust, triggers a cascade of events that culminates in AEP."

RECOMMENDATIONS FOR MEDICAL SURVEILLANCE AND REFERRAL

Current Military Medical Screening and Surveillance Procedures

Current military accession procedures include predeployment health evaluation by history, physical examination, and routine vision and hearing screening. Baseline PFT is not performed unless there is a medical indication (ie, a request for waiver from an applicant with asthma after age 12 years) or for certain military occupations (eg, firefighters) with more stringent medical screening requirements based on job description. An indirect measure of pulmonary capacity that is required for all active duty military is the test of physical fitness or readiness based on the 2-mile run time. Although the physical readiness testing differs between service branches, all service members are required to pass a 1.5- to 3-mile run (adjusted for age and sex) on a semiannual basis. Worsening of physical fitness run times may be an indicator of underlying lung disease, and may be useful in identifying those who require further diagnostic evaluation.

Within 2 weeks at the end of a deployment, military personnel complete health questionnaires as part of a Post Deployment Health Assessment (PDHA), followed 3 to 6 months later by the Post Deployment Health Reassessment (PDHRA) examination. Although information collected during these examinations is limited to findings on a short questionnaire, the PDHRA examination may provide a useful structure with which to expand military medical surveillance efforts.

Recommendations to Enhance Military Medical Surveillance for Pulmonary Disease

Given concerns about increased risk for lung disease in returning military personnel, the Working Group discussed ways to enhance medical surveillance for lung disease detection and referral. The Working Group recognizes that some service members may have supranormal pulmonary function when compared with population norms and that such comparisons may be insensitive in detecting declines in a postdeployment military population. Although resting PFT is effort-dependent and insensitive in the diagnosis of some lung conditions, serial spirometry has been used effectively in occupational settings to identify individual and population trends in lung function over time, particularly in those at risk for occupational airways diseases.

Potential at-risk populations

Because current exposure monitoring data and information about individual locations and exposures during deployment are insufficient to identify risk groups based on exposure, the Working Group recommends that all US troops deployed to Iraq and Afghanistan for at least 30 days (based on the DoD definition of minimum time to qualify as deployment) be included in the medical surveillance program and that all deployed personnel undergo pre- and postdeployment respiratory disease surveillance.

Recommended components of medical surveillance

The Working Group recommends predeployment administration of a standardized respiratory health questionnaire, baseline spirometry (meeting American Thoracic Society criteria for quality and reproducibility), and the military Physical Readiness Test (or Physical Fitness Test). The respiratory health questionnaire should focus on demographic information, current respiratory symptoms (cough, sputum, dyspnea on exertion, wheeze), smoking history, body mass index, previous lung disease, and job duties. Testing should be performed shortly before deployment and again 3 to 6 months after deployment at the time of the PDHRA examination.

Provider qualifications

Medical surveillance should be supervised by a licensed physician familiar with spirometry testing acceptability and reproducibility criteria[22] and with training in the interpretation of spirometry. Optimal physician oversight includes administration, review and interpretation of the respiratory health questionnaire, spirometry results (including assessment of spirometry quality), and Physical Readiness/Fitness Test findings. Access to predeployment results is essential for comparison with postdeployment findings, as the at-risk population is likely to have high normal clinical results before deployment.

Recommended Criteria for Diagnostic Referral

The Working Group discussed several possible approaches to individual referral for further diagnostic evaluation based on findings from medical surveillance. Given current uncertainties about scope of the problem and risks for lung disease, the group recommends greater inclusivity in testing and less stringent criteria for diagnostic referral until further information is obtained. Table 2 outlines the findings that should prompt further diagnostic evaluation.

TABLE 2. Findings on Postdeployment Medical Testing That Should Prompt Diagnostic Referral

Persistent (more than 3 months), unexplained cough, shortness of breath, or wheezing/chest tightness
Any abnormal spirometry pattern (below the lower limit of normal)
Excessive decline in forced expiratory volume in 1 s or forced vital capacity, defined as a 15% or more decrease in either parameter between pre- and postdeployment testing, even if spirometry is within the normal range
A 10% or more decline comparing pre- and postdeployment spirometry if new onset respiratory symptoms are also reported
Excessive decline in Physical Readiness Test compared with predeployment testing

TABLE 3. Recommended Approach to Diagnostic Testing for Postdeployment Patients Referred for Further Evaluation

Comprehensive medical questionnaire, including full occupational exposure history
Physical examination, with particular attention to cardiopulmonary findings and body mass index
Full pulmonary function tests (lung volumes, DLCO, pre- and postbronchodilator spirometry
Methacholine challenge
High-resolution computed tomography—prone and supine, expiratory views
Maximum exercise tolerance testing with arterial blood gases and full metabolic exercise
Consider referral for surgical lung biopsy to assess constrictive bronchiolitis on a case-by-case basis

DLCO, diffusion capacity for carbon monoxide.

Recommended Standardized Diagnostic Approach

Table 3 outlines the Working Group's recommendations for diagnostic evaluation of those referred for possible deployment-related lung disease based on medical surveillance findings. The initial approach should include a complete occupational/environmental and medical history questionnaire along with complete PFTs and chest HRCT with both inspiratory and expiratory views and prone/supine imaging. Pulmonary function tests should include pre- and postbronchodilator lung volumes, spirometry, and diffusing capacity for carbon monoxide. The primary purpose of complete PFTs is to assess the presence of fixed or reversible airflow obstruction, suggesting either CB or asthma, respectively. Although chest HRCT findings of expiratory heterogeneous air trapping, cylindrical bronchiectasis, mosaic attenuation, and patchy ground-glass opacities are often seen in patients with bronchiolitis, the sensitivity of HRCT for early disease detection is unclear. Other tests that should be considered in the diagnostic approach to patients with postdeployment lung abnormalities include methacholine challenge and metabolic exercise testing to assess for ventilatory, cardiac, and gas exchange abnormalities.

The role of lung biopsy in the evaluation of patients with possible postdeployment lung disease is uncertain. If the evaluating pulmonary specialist recommends biopsy, a surgical thoracoscopic biopsy should be obtained, because transbronchial lung biopsies are generally inadequate for diagnosis of CB. Patients who are considered for this invasive procedure should be clearly informed of the risks and uncertainties in diagnosis. The interpreting pathologist should be aware of the concern for possible CB so that appropriate tissue staining can be performed. Ideally, the Working Group recommends the creation of a panel of recognized pulmonary pathologists to provide consistency in lung tissue staining and interpretation.

Proposed Case Definitions

In an effort to establish consensus regarding diagnostic criteria and to facilitate data tracking and case management, the Working

TABLE 4. Proposed Case Definitions for Deployment-Related Asthma and Constrictive Bronchiolitis

Deployment-related asthma
Postdeployment onset of persistent respiratory symptoms (shortness of breath, cough, wheezing, chest tightness) and *either*
Reversible airflow limitation on pre- and postbronchodilator pulmonary function tests
Positive methacholine challenge
Deployment-related constrictive bronchiolitis
Postdeployment onset of persistent respiratory symptoms and at least two of the following:
Fixed airflow limitation on pre- and postbronchodilator pulmonary function tests with no other explanation
Mosaic attenuation/air trapping on expiratory high-resolution computed tomography
Clinically significant gas exchange abnormalities or abnormal maximum oxygen consumption on exercise tolerance testing, with no other clinical explanation
Surgical lung biopsy findings of constrictive bronchiolitis, as determined by an experienced pulmonary pathologist

Group discussed case definitions for deployment-related lung disease. Proposed definitions for deployment-related asthma and CB are contained in Table 4. The Working Group recognized that the proposed asthma definition may miss some with asthma or asthma-like symptoms in whom airflow reversibility can be difficult to document, especially in patients already on asthma treatment or who report worsening of predeployment asthma.

FUTURE NEEDS AND DIRECTIONS

Perhaps the greatest challenge for the Working Group and for those in policy positions within US military medical programs is the lack of information about the scope and extent of deployment-related lung disease. There are a number of reasons for this lack of clarity. First, epidemiological studies rely on self-reported symptoms or conditions and on *International Classification of Diseases* codes that may be variably invoked, making it difficult to say with certainty which conditions are increasing in incidence or prevalence. Second, with regard to inhalational exposures, it is generally recognized that PM exposure is ubiquitous in the current theatres of operation; that episodic exposure extremes such as those from industrial fires are difficult to characterize and may confer particular risk; that burn pits of varying size and composition have been used; and that inhalational exposures to desert dust storms as well as vehicular and industrial emissions vary based on location. Moreover, the lung diseases of concern, particularly CB, are often difficult to diagnose and require a high index of clinical suspicion and diagnostic expertise.

Despite these constraints, given the potential impacts of the lung diseases of concern, a well-designed medical surveillance and disease management program is essential to characterize as well as prevent or minimize risk. The Working Group discussed a number of logistical and operational challenges to creating such a program. A major effort should be focused on assuring access to pre- and postdeployment spirometry of high quality at all transfer sites for military personnel. The PDHA and the PDHRA systems provide a ready framework into which spirometry and other relevant clinical data for active duty personnel can be added, although this effort will require substantial additional training and equipment needs. It is essential that these processes and information are coordinated with the Veterans Affairs administration for those service members who are already veterans at the time of their PDHA and PDHRA. Inclusion of deployed members of the National Guard/Reserves in appropriate medical surveillance is essential.

A standardized questionnaire should be developed to collect exposure data and gather information about medical and social risk factors, both for clinical assessment and for use in case–control and other research investigations. Components of the occupational and environmental exposure histories should include, at minimum, dates and durations of deployment, deployment location, job duties, and proximity to specific exposure events (eg, the Mishraq sulfur mine fire). Given the challenges of medical diagnosis and management, the Working Group recommends that diagnostic centers with expertise in the lung diseases of concern be identified for patient referral, so that collaboration and information can be optimally shared. This will enable further refinement of clinical, imaging, and pathology protocols, particularly given the need for uniform evaluation of patients being considered for surgical lung biopsy. The criteria and circumstances for patient referral for an invasive surgical lung biopsy remain uncertain, and the Working Group is mindful of the need to further clarify the indications for surgical lung biopsy as more information becomes available.

Information from DoD, Veterans Affairs, and academic medical centers needs to be collected and examined systematically, with attention to Health Insurance Portability and Accountability Act and other patient protection requirements. There should be a review of all military personnel with new diagnoses of chronic lung disease since 2002, including asthma, chronic bronchitis, emphysema, chronic obstructive pulmonary disease, bronchiolitis, new interstitial lung disease, AEP (as is already being done at Landstuhl Regional Medical Center), and bronchiolitis obliterans (with and without organizing pneumonia). Pulmonologists at Brooke Army Medical Center who participated in the Working Group have recently established a number of ongoing protocols to help to define the extent of chronic respiratory diseases in deployed military personnel, and these protocols may serve as models for expanded data collection and analysis.

Disability management is another challenge that will require coordination of DoD and Department of Veterans Affairs systems to assure a seamless transition of impaired active duty personnel to veterans' medical care systems. The Working Group endorsed the use of pilot approaches to developing integrated Compensation and Pension examinations, important in assuring more efficient and less duplicative processing of injured active and inactive military personnel, and to facilitate data collection and analysis for respiratory disease.

Additional research is needed on the health effects of complex inhalational exposures facing military personnel in areas of deployment. Animal toxicology studies of desert and burn pit dusts are necessary to understand exposure-related airway effects. Further epidemiologic investigations of deployed populations, in combination with more comprehensive exposure assessment, are essential. Of note, populations potentially at risk are not limited to military personnel, and epidemiologic efforts should also consider contract workers such as those with the Army Corps of Engineers, private contractors, Iraqi and Afghan nationals working with the US military, and perhaps even embedded press corps. The Institute of Medicine[9] has recently recommended an epidemiologic initiative focused on burn-pit exposures and illnesses to address a number of these unanswered questions.

Soldiers experiencing postdeployment respiratory disorders represent a heterogeneous group. To date, there are no studies offering specific recommendations for medical management of this population. Those diagnosed with asthma, rhinitis, or bronchitis should be treated on the basis of standard guidelines. We know of no data to guide treatment of those with CB. Future clinical and translational research efforts will be important both in understanding the pathogenesis and in guiding treatment of lung diseases in affected military personnel.

Although the Working Group focused on medical surveillance and diagnosis of personnel returning from deployment in southwest

Asia, we recognize that primary prevention remains the major priority for all occupational lung diseases. Efforts are being focused on elimination of open-air burn pits along with improved education and enforcement on what cannot be burned in open settings. Interventions such as appropriate use of respiratory protection and improved communication to increase awareness of exposure risks and avoidance are essential. Through collaborations with all branches of the DoD, the Veterans Affairs administration, and academic medical centers, it should be possible to address the risk factors for and clinical recognition and management of these adverse respiratory outcomes and apply best practices for their prevention and control.

REFERENCES

1. Weese CB, Abraham JH. Potential health implications associated with particulate matter exposure in deployed settings in southwest Asia. *Inhal Toxicol*. 2009;21:291–296.
2. *Working Group on Post-Deployment Lung Disease*. Denver, CO: National Jewish Health; 2010.
3. Sanders JW, Putnam SD, Frankart C, et al. Impact of illness and non-combat injury during Operations Iraqi Freedom and Enduring Freedom (Afghanistan). *Am J Trop Med Hyg*. 2005;73:713–719.
4. Smith B, Wong CA, Smith TC, Boyko EJ, Gackstetter GD. Newly reported respiratory symptoms and conditions among military personnel deployed to Iraq and Afghanistan: a prospective population-based study. *Am J Epidemiol*. 2009;170:1433–1442.
5. King MS, Eisenberg R, Newman JH, et al. Constrictive bronchiolitis in soldiers returning from Iraq and Afghanistan. *N Engl J Med*. 2011;365:222–230.
6. Szema AM, Peters MC, Weissinger KM, Gagliano CA, Chen JJ. New-onset asthma among soldiers serving in Iraq and Afghanistan. *Allergy Asthma Proc*. 2010;31:67–71.
7. Technical bulletin 593, EPA Solid Waste Disposal Act, Defense Logistics Agency.
8. Furlow B. US Institute of Medicine studies military burn pits. *Lancet Oncol*. 2010;11:316.
9. Institute of Medicine. *Long-Term Health Consequences of Exposure to Burn Pits in Iraq and Afghanistan*. Washington, DC: National Academies Press; 2011.
10. Lange JL, Schwartz DA, Doebbeling BN, Heller JM, Thorne PS. Exposures to the Kuwait oil fires and their association with asthma and bronchitis among gulf war veterans. *Environ Health Perspect*. 2002;110:1141–1146.
11. US Army Center for Health Promotion and Preventive Medicine. *Health Assessment of 2003 Al Mishraq Sulfur Fire Incident*. Aberdeen Proving Ground, MD: US Army Center for Health Promotion and Preventive Medicine; 2007.
12. Mosher D, Lachman B, Greenbert M, et al. *Green Warriors: Army Environmental Considerations for Contingency Operations From Planning Through Post-Conflict*. United States Army. Santa Monica, CA: RAND; 2008.
13. Engelbrecht JP, McDonald EV, Gillies JA, et al. Characterizing mineral dusts and other aerosols from the Middle East–Part 1: ambient sampling. *Inhal Toxicol*. 2009;21:297–326.
14. Kim H, Herbert R, Moline J, et al. The prevalence of asthma among 20,843 World Trade Center responders [abstract]. *Chest*. 2009;136:25S–b.
15. Brackbill RM, Hadler JL, DiGrande L, et al. Asthma and posttraumatic stress symptoms 5 to 6 years following exposure to the World Trade Center terrorist attack. *JAMA*. 2009;302:502–516.
16. Roop SA, Niven AS, Calvin BE, Bader J, Zacher LL. The prevalence and impact of respiratory symptoms in asthmatics and nonasthmatics during deployment. *Mil Med*. 2007;172:1264–1269.
17. Apkinar-Elci M, Travis WD, Lynch DA, Kreiss K. Bronchiolitis obliterans syndrome in popcorn production plant workers. *Eur Respir J*. 2004;24:298–302.
18. King TE. Bronchiolitis. In: King TJ, Schwarz MI, eds. *Interstitial Lung Disease*. Hamilton, Ontario, Canada: BC Decker; 2003.
19. Devakonda A, Raoof S, Sung A, Travis WD, Naidich D. Bronchiolar disorders: a clinical-radiological diagnostic algorithm. *Chest*. 2010;137:938–951.
20. Visscher DW, Myers JL. Bronchiolitis: the pathologist's perspective. *Proc Am Thorac Soc*. 2006;3:41–47.
21. Shorr AF, Scoville SL, Cersovsky SB, et al. Acute eosinophilic pneumonia among US Military personnel deployed in or near Iraq. *JAMA*. 2004;292:2997–3005.
22. Miller M, Hankinson J, Brusasco V, et al. Series: ATS/ERS Task Force: Standardisation of lung function testing. *Eur Respir J*. 2005;26:319–338.

