Diagnosis and management of chronic lung disease in deployed military personnel

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Abstract: Military personnel are a unique group of individuals referred to the pulmonary physician for evaluation. Despite accession standards that limit entrance into the military for individuals with various pre-existing lung diseases, the most common disorders found in the general population such as asthma and chronic obstructive pulmonary disease remain frequently diagnosed. Military personnel generally tend to be a more physically fit population who are required to exercise on a regular basis and as such may have earlier presentations of disease than their civilian counterparts. Exertional dyspnea is a common complaint; establishing a diagnosis may be challenging given the subtle nature of symptoms and lack of specificity with pulmonary function testing. The conflicts over the past 10 years in Iraq and Afghanistan have also given rise to new challenges for deployed military. Various respiratory hazards in the deployed environment include suspended geologic dusts, burn pits, vehicle exhaust emissions, industrial air pollution, and isolated exposure incidents and may give rise to both acute respiratory symptoms and chronic lung disease. In the evaluation of deployed military personnel, establishing the presence of actual pulmonary disease and the relationship of existing disease to deployment is an ongoing issue to both military and civilian physicians. This paper reviews the current evidence for chronic lung disease in the deployed military population and addresses any differences in diagnosis and management.

Keywords: airborne hazards, asthma, deployment, military personnel, particulate matter

Introduction

Deployed military personnel face numerous challenges in the performance of their duties. While these individuals are generally healthy given the medical requirements for military service, numerous issues can arise. Primary among these is the possible risk for injury due to conventional and unconventional warfare (e.g. improvised explosive devices). Much attention in military medicine has been given to the chronic effects of traumatic limb amputations, burn injury, traumatic brain injury, and post-traumatic stress disorder. Other nontraumatic health effects such as increased respiratory symptoms may occur due to the austere nature and desert environment of the current theaters of operations in Southwest Asia (SWA), primarily Iraq and Afghanistan [Kroenke *et al.* 1998; Petruccelli *et al.* 1999]. Respiratory symptoms may be due to potential airborne hazards, including high levels of ambient particulate matter (PM) from suspended geologic dusts, industrial air pollution, and burn pit emissions from the incineration of military waste materials. Numerous reports in various types of electronic and print media have implied that there is a direct relationship between PM exposure during deployments over the past 10 years and the development of serious and debilitating chronic pulmonary disease [Weese and Abraham, 2009]. Several anecdotal cases of military personnel with lung disease have also been detailed in various news media articles, suggesting there is a systemic problem with undiagnosed pulmonary disease in returning service members [Risen, 2010]. The current medical literature clearly shows an increase in respiratory symptoms in deployed military, but provides little evidence or longitudinal data on development of chronic lung disease [Smith *et al.* 2009; Institute of Medicine, 2011].

The US Army Medical Department, Veterans Administration (VA), and other research agencies within the Department of Defense (DoD) are actively pursuing numerous scientific investigations

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into deployment lung disease to better define the severity and prevalence of acute and chronic respiratory disease. Several important questions have been raised about airborne hazards and other environmental exposures during deployment: What is the current scientific evidence existing in the medical literature linking chronic lung disease related to military deployment? What are the current investigations into deployment-related respiratory disease? How should the clinical evaluation of the postdeployment military patient with respiratory symptoms differ from that of other patients? This article reviews what is currently known about the frequency of respiratory symptoms, the diagnostic approach to these symptoms in military personnel, and recommends any differences in disease management due to fitness requirements and deployment to austere environments.

Airborne hazards during deployment

Environmental surveillance

Military personnel in SWA have been exposed to increased levels of airborne PM since early in Operations Iraqi Freedom and Enduring Freedom (OIF/OEF) [Weese and Abraham, 2009]. Adverse health effects, including cardiovascular and pulmonary disease, are potential consequences of exposure to high levels of PM with aerodynamic diameter of less than 10 μm (PM_{10}) and especially less than 2.5 μm ($PM_{2.5}$). The severity of the effect depends on the amount and duration of the exposure, the physical and chemical characteristics of the PM, and the underlying health of the exposed individuals [Davidson *et al.* 2005]. The Joint Particulate Matter Working Group was chartered in 2005 to begin investigations into potential health issues related to this ongoing PM exposure. A significant knowledge gap was a lack of the physical and chemical characterization of the PM and assessment of its toxicity. In response to this recommendation, the US Army Public Health Command (USAPHC) commenced the Enhanced Particulate Matter Surveillance Program which collected ambient PM from 15 locations throughout the Central Command area of operations in Iraq and Afghanistan over approximately a year and extensively characterized the physical, chemical, and mineralogical properties [Engelbrecht *et al.* 2009]. The study demonstrated the three main air pollutant types to be geological dust, smoke from burn pits, and heavy metal condensates. The quartz grains had rounded edges and mineral grains were coated by clay minerals and iron oxides. Sampling of burn pit emissions was also conducted at Joint Base Balad where the largest burn pit (10 acres in size) in Iraq was located; the 1-year military exposure guidelines for PM were exceeded in the 52 collected samples, of which 50 were related to an increase in PM_{10}. These PM levels were typical of the region and similar to background levels not in proximity to the burn pit. No metals or polycyclic aromatic hydrocarbons above the 1-year exposure guidelines were detected in the PM samples, while volatile organic compounds were exceeded only twice [US Army Center for Health Promotion and Preventive Medicine, 2008].

Southwest Asia particulate matter

The Joint Particulate Matter Working Group also recommended that the pathogenicity and toxicity of SWA dusts be evaluated. Naval researchers in collaboration with US Army Corps of Engineers are engaged in efforts to characterize the soil and PM microbiota from Iraq and Afghanistan to address potential health risks from novel pathogens. Laboratory work conducted with PM dust from Kuwait by the Navy Environmental Health Effects Laboratory showed no long-term toxicity in exposed rats [Wilfong *et al.* 2011], and 2-week inhalational exposures of rats to Iraq surface soil fines also by the Navy Environmental Health Effects Laboratory did not induce notable adverse responses in the animals. The findings of both these studies are consistent with independently conducted rat studies using intratracheally instilled PM from Iraq by the US Army Center for Environmental Health Research and National Institute for Occupational Safety and Health. Minimal chronic effects on the lung were observed 150 days post exposure and were similar to urban dust exposure (Jackson, 2011). There are ongoing studies that continue to examine the unique PM from this area along with potential interactions with burn pit smoke.

Respiratory symptoms

There have been reported increases in respiratory symptoms such as cough and dyspnea during deployment dating back to 1990–1991 during Operations Desert Shield/Storm. From initial reports on the health effects of the Kuwait oil fires of 1991 among US troops, surveys by Army investigators found an increase in reported symptoms of upper respiratory tract irritation, shortness of breath, and cough associated with proximity to

these fires. The symptoms generally resolved once the exposure ceased but no long-term follow up on these patients was conducted [Petruccelli *et al.* 1999]. Further survey research in a cohort of 1560 veterans based on oil-fire proximity conducted 5 years after the First Gulf War did not find a correlation in self-reported symptoms of asthma and bronchitis and modeled proximity exposures. The authors concluded that oil fire smoke exposure was not the cause of increased respiratory symptoms [Lange *et al.* 2002]. Review of hospitalization data from the theaters of operation did not demonstrate an increase in military treatment facility admissions related to oil-fire exposure or respiratory disease [Smith *et al.* 2002, 2004]. Long-term respiratory outcomes 10 years post deployment did not increase in a deployed cohort from the First Gulf War [Karlinsky *et al.* 2004]. The initial survey results from OIF/OEF of 15,000 redeploying military personnel from Iraq and Afghanistan estimated that 69.1% reported experiencing respiratory illnesses, of which 17% required medical care [Sanders *et al.* 2005]. The Millennium Cohort Study is a longitudinal study conducted by the Naval Health Research Center designed to evaluate the long-term health effects of military service members. Initial data from the baseline and initial follow-up survey of 46,077 military personnel (10,753 deployed) found higher rates of newly reported respiratory symptoms in deployed compared to nondeployed personnel (14% *versus* 10%), although similar rates of chronic bronchitis/emphysema (1% *versus* 1%) and asthma (1% *versus* 1%) were observed. Deployment was associated with increased respiratory symptoms independently of smoking status. The authors suggested that specific exposures rather than deployment may be a determinant of postdeployment respiratory illness [Smith *et al.* 2009].

One confounding factor in evaluating respiratory symptoms in deployed service members is the higher prevalence of tobacco use in the military and its increased use during deployment. The 2006 National Health Interview Survey estimated that 23.5% of men and 18.1% of women in the USA were smokers. The 2008 Defense Lifestyle Assessment Program also noted an overall prevalence of cigarette smoking at 30% (compared with 29% in civilians) with higher prevalence of 38% in the Marine Corps [Bray *et al.* 2009]. A recent survey of soldiers deployed to Iraq reported that 51.9% of men and 41.7% of women were using tobacco products before deployment; 58.3% of men and 52.1% of women were using tobacco during deployment, and 25.4% of men and 48% of women increased use of tobacco during deployment [DiNicola and Seltzer, 2010].

Despite the increase in respiratory symptoms associated with deployment noted in these surveys, short-term respiratory health effects due to specific exposures have not been identified. Epidemiologic research conducted by the USAPHC of the enhanced PM surveillance sites found no association with increased PM exposures and acute cardiorespiratory events requiring medical encounters (adjusted odds ratio of 0.92 and 0.99, respectively for 10 $\mu g/m^3$ increases in $PM_{2.5}$ and PM_{10}) [Abraham and Baird, 2012]. The 2010 Armed Forces Health Surveillance Center reported on the potential health impacts of burn pit emissions and concluded the overall preliminary findings indicate, at this time, no substantial or consistent health effects in personnel assigned to locations with burn pits at the bases examined, on a population-wide basis, compared with other deployers. Furthermore, these findings are consistent with the earlier Joint Base Balad Burn Pit Health Risk Assessment accomplished in 2008 [Armed Forces Health Surveillance Center, 2010]. A 2011 Institute of Medicine report, *Long-term Health Consequences of Exposure to Burn Pits in Iraq and Afghanistan* came to a similar conclusion based on the available evidence [Institute of Medicine, 2011].

Lung diseases

The association between chronic lung disease and deployment has yet to be firmly established based on the lack of available short-term or longitudinal studies. With the exception of acute eosinophilic pneumonia (AEP), most evidence is based on retrospective data of patient coding or case series. Further data are currently being collected through a variety of studies by DoD and VA researchers on active duty military personnel and veterans.

Acute eosinophilic pneumonia

There is definite evidence for a cluster of AEP cases related to deployment in military personnel. Eighteen cases of AEP were initially reported from March 2003 to March 2004 among 183,000 military personnel deployed in or near Iraq [Shorr *et al.* 2004]. AEP is an unusual disease of unknown etiology characterized by acute illness (less than 2 weeks of symptoms), respiratory failure, bilateral pulmonary infiltrates, hypoxia, and predominant

eosinophilia (25%) on bronchoalveolar lavage (BAL) [Allen *et al.* 1989]. Extensive evaluation failed to demonstrate an infectious etiology or association with known causes and no geographic clustering was evident. New-onset smoking was considered a risk factor in these cases as all patients were smokers and 78% reported recent onset of smoking [Shorr *et al.* 2004]. Continued collection of data from Landstuhl Regional Medical Center in Germany (the primary evacuation center for military patients from SWA) now shows there have been 44 diagnosed cases with an average BAL eosinophilia of 36.8 ± 20.9%. Ninety-three percent of the patients were smokers and 65% required mechanical ventilation [Sine *et al.* 2011]. The frequency of AEP in the deployed population has significantly changed the management of acute pulmonary disorders from the theater for definitive diagnosis and treatment. The combat support and evacuation hospitals are very cognizant of AEP symptoms and aeromedically evacuate all cases of new symptoms of acute dyspnea with bilateral infiltrates immediately from theater to Germany. Generally, steroid treatment has been initiated, and upon arrival, these patients undergo fiberoptic bronchoscopy to determine the presence of pulmonary eosinophilia. Apart from two early deaths, no further military personnel have died from this syndrome.

Asthma

Limited data exist on the effects of deployment on asthma. The current guidelines for accession of new military personnel are service specific, but in general, an established diagnosis of asthma after the age of 12 has been an exclusion criterion. Despite these restrictions, asthma remains a common finding in military personnel that may mirror the incidence in the general population. A 2002 study by Army researchers found that nearly half of military patients with exertional dyspnea had either asthma or exercise-induced bronchospasm [Morris *et al.* 2002]. The extreme climate conditions in SWA along with high PM exposures due to dusts or burn pit smoke could contribute to poor asthma control with increased exacerbations. A survey of Army personnel identified 5% of troops deployed to SWA reported a previous diagnosis of asthma [Roop *et al.* 2007]. While people with asthma had poor control of symptoms, people with asthma and those without both reported significantly increased respiratory symptoms during deployment. A retrospective review of over 6000 VA medical records [based on International Classification of Disease ninth revision diagnostic codes with limited pulmonary function testing (PFT) data] noted higher rates of 'new-onset' asthma in deployed military between 2004 and 2007 compared with nondeployed personnel stationed in the USA (6.6% *versus* 4.3%) [Szema *et al.* 2010]. An in-depth review by DoD investigators on patients with asthma undergoing a formal medical fitness for duty evaluation could not establish a relationship between the diagnosis of asthma and deployment. In reviewing 400 patient records, an asthma diagnosis was confirmed in 78% of the patients either by spirometry or bronchoprovocation testing (BPT). Only 25% of patients with asthma were diagnosed post deployment and no differences in PFTs or asthma severity were noted based on deployment history [Delvecchio *et al.* 2010].

Management of asthma in deployed environments varies depending on the individual patient needs and severity of asthma. There is no absolute restriction for military personnel with the diagnosis of asthma to be exempted from deployment to Iraq and Afghanistan. Limitations do exist for patients with asthma who have significant limitations in duty performance or require extensive regular treatments, such as chronic oral steroid use or previous history of hospitalizations or intubations. Commonly, patients with mild to moderate asthma with controlled disease on either inhaled controllers or as-needed β agonists have been deployed. The clinician managing these patients prior to deployment should take into consideration the location of deployment and accessibility to regular follow up in fixed medical facilities. Determining the severity of asthma based on spirometry should be done to establish a baseline for treatment considerations. Higher doses of inhaled corticosteroids may be warranted in anticipation of the level of potential airborne exposures. The patient should be prescribed adequate doses of medications to manage the first month of deployment and be placed on asthma medications that can be resupplied in theater. Once in the deployed setting, management will depend primarily on the level of symptoms; a stepwise approach may not be warranted. If the patient has never been deployed and develops moderate to severe symptoms, consideration may be given to oral steroids or evacuating the patient from theater. Managing the chronic asthmatic in a deployed setting may require a higher level of expertise than what can be provided by a physician's assistant or brigade surgeon. Ultimately,

treatment decisions are based on balancing the health of the service member without affecting execution of the military mission.

Chronic lung diseases

Constrictive bronchiolitis (CB) (or bronchiolitis obliterans), is a lung disease characterized by fixed airways obstruction and fibrosis of the distal airways or bronchioles, with extrinsic narrowing or obliteration of the bronchiolar lumen [Myers and Colby, 1993]. It is associated with environmental and occupational inhalation exposures, classically following exposure to nitrogen and sulfur dioxides, and may cause permanent respiratory impairment. The clinical syndrome of CB usually presents with subtle onset of exertional shortness of breath and nonproductive cough. Spirometry will typically show airflow obstruction without postbronchodilator increase and high resolution computed tomography (CT) scanning of the chest often shows heterogeneous air trapping most prominent on expiratory imaging, sometimes with areas of patchy ground glass opacities and scattered cylindrical bronchiectasis [Garg *et al.* 1994]. In 2011, King and colleagues reported on a case series of 80 previously deployed military personnel, 49 of whom underwent surgical lung biopsy and in whom a pathologic diagnosis of CB was made in 73% [King *et al.* 2011]. The patients comprising the case series had varied deployment exposures; less than half had exposure to a month long 2003 sulfur mine fire in Iraq. Most soldiers had symptoms only with high levels of exercise. Half were reported to have a reduced carbon monoxide diffusing capacity (mean value of 73.4 ± 15.4), 16% had evidence of obstruction or restriction. CT imaging likewise only showed 'mild air trapping' in 16% and the typical radiographic pattern of mosaicism was not described. Methacholine challenge testing (MCT) was only performed in 32% of soldiers; no information was provided on postbronchodilator testing or laryngoscopy. Many of the soldiers left the military and no longitudinal data were presented on their clinical course. Furthermore, an epidemiologic comparison demonstrated no increase in postdeployment medical encounters among military personnel exposed to the 2003 Mishraq sulfur fire compared with unexposed personnel stating: 'This exploratory analysis did not show a definite link between sulfur fire exposure in Iraq and either chronic or recurring respiratory diseases' [Baird et al. 2012]. A blinded review of the biopsy sample from the study is currently being undertaken to validate the pathologic findings. A further comprehensive review of the DoD electronic medical records failed to identify any further cases of deployment-related CB apart from those soldiers evaluated at a single medical center.

Development of a pulmonary health research program

Prompted by the concerns raised in the press and by anecdotal and case report data about the pulmonary health of returning military personnel, an initial working group convened in February 2010 at National Jewish Health in Denver. The convened group included civilian and military experts in airborne hazards and respiratory diseases, and examined the limited available evidence to develop a general consensus for further investigations. Some general recommendations included conducting standardized pre- and postdeployment medical surveillance; establishing criteria for medical referral and diagnosis; and developing case definitions for key deployment-related lung diseases [Rose *et al.* 2012]. It was clear that a coordinated effort to resolve issues related to deployment-related respiratory disease would be required because available data were limited. In response to this problem, a new Pulmonary Health Task Area was proposed by the Military Operational Medicine Research Program of the US Army Medical Research and Materiel Command. In June 2010, the Pulmonary Health Task Area Working Group proposed priorities for research in four areas: clinical research, animal models of toxicity, biomarkers, and exposure assessment/epidemiology. Four major data gaps identified during the conference included prevalence and severity of deployment-related disease, methods for diagnosis and screening, intervention and treatment, and toxicity and pathogenicity of SWA PM. The Pulmonary Health Task Area met again to provide updates on research activities in December 2011. These efforts were further expanded by the VA/DoD Health Executive Council Deployment Health Working Group that developed four joint activities between the DoD and VA. These activities included follow-up medical care of deployed populations; outreach and health risk communication products; surveillance; and research initiatives. The first joint VA/DoD Airborne Hazards Symposium was held in August 2012 with a pending monograph of the proceedings currently in preparation.

Table 1. Potential differences between military and general civilian population.

Younger population
Better overall cardiovascular fitness
Mandatory regular exercise
Higher prevalence of smoking [DiNicola *et al.* 2010]
Transient population with multiple assignments
Frequent deployments with various exposures
Earlier presentation of pulmonary disease
Differing perception of dyspnea

Evaluation of deployed military personnel

The evaluation of deployed military personnel can be challenging. As outlined above, environmental exposures are ubiquitous, varied, and susceptible individuals may either develop new pulmonary symptoms or exacerbate pre-existing disease. Despite these reported exposures, the evidence for uncommon lung disease is scant and the military population will have the same types of pulmonary disorders as seen in the general population. However, these individuals are different in that they are younger, are generally more fit, and may have an earlier presentation of symptoms (see Table 1). A predeployment study of exertional dyspnea in military personnel by Morris and colleagues demonstrated the unique nature of their pulmonary disease [Morris *et al.* 2002]. Patients, all of whom reported exertional dyspnea, were evaluated in a standardized manner with chest imaging, complete PFTs, cardiac evaluation, exercise laryngoscopy, BPT, and cardiopulmonary exercise testing (CPET). Nearly half of the study population had either asthma or exercise-induced bronchospasm. A more interesting finding was the 25% of the evaluated patients who had no identifiable abnormalities despite a comprehensive evaluation. Other significant findings were the 10% of patients with vocal cord dysfunction (VCD) and the lack of any cardiac disease identified in this cohort [Morris *et al.* 2002].

Exertional dyspnea is the most common pulmonary complaint in the military population. Patients with exertional dyspnea typically complain of difficulty with running during mandatory physical training or an inability to meet the requirements for the timed run during fitness testing. Associated complaints may include cough, chest tightness, or wheezing during exercise. Any unexplained cough, shortness of breath, wheezing, chest tightness for more than 3 months should prompt a basic evaluation. Most important in the initial evaluation should be documentation of deployment, relationship of deployment to symptoms, and any specific exposure. At the primary care or initial evaluation, the minimum required tests should include at least spirometry and a chest radiograph. A properly performed spirometry can establish the presence of abnormalities and serve as starting point for further testing. The patient with obstruction or a 12% increase in forced expiratory volume at 1 s post bronchodilator and associated clinical symptoms should be initially treated for asthma. Restrictive indices on spirometry should indicate a referral for full PFTs. Chest radiographs are typically normal but may identify disorders such as sarcoidosis, interstitial lung disease, or congenital lung abnormalities.

Pulmonary diagnostic evaluation

The patient with exertional symptoms and a normal spirometry represents the biggest challenge in the evaluation of postdeployment respiratory symptoms. While there is no standardized approach for all patients based on normal PFT and radiographic findings, our general algorithm is shown in Figure 1. When testing is negative for a given step, we will proceed to additional testing in this stepwise fashion.

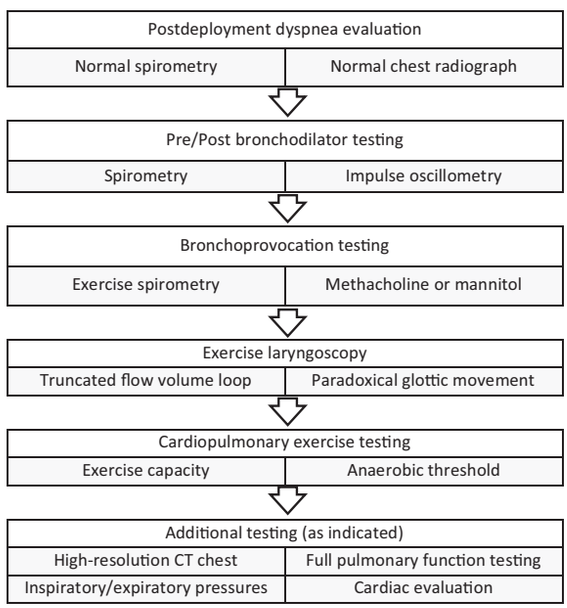

Figure 1. Proposed diagnostic algorithm for evaluation of deployed military personnel.

(1) CBC: a complete blood count with differential should be obtained in all patients. Anemia may be more common in women and should be ruled out as a potential etiology. Additionally, the presence of eosinophils in a patient with atopy may suggest underlying asthma as the etiology.
(2) Chest imaging: a chest radiograph should suffice in most patients with exertional dyspnea and is typically normal. Because of the reported cases of CB in redeploying soldiers, our current practice is to obtain high-resolution CT scans of the chest to evaluate for evidence of occult interstitial changes, air trapping, or bronchiectasis. This approach did not prove to be diagnostic in our ongoing study of soldiers within 6 months of redeployment with only minor abnormalities found in 6% of patients [Dodson *et al.* 2011]. However, high-resolution CT should definitely be obtained in patients with interstitial changes, restrictive PFTs or evidence of fixed obstruction on spirometry
(3) PFT:

    (a) Spirometry with postbronchodilator testing: given the significant percentage of patients with underlying airway hyperresponsiveness (AHR) in this population, even if normal spirometry has been obtained, repeat testing post bronchodilator (or during active symptoms) is recommended [Nish and Schwietz, 1992].
    (b) Flow volume loop: additional consideration should be given to the appearance of the inspiratory flow volume loop in particular. Only 25% of patients with VCD have evidence of truncation or flattening of the flow volume loop at rest [Morris *et al.* 2002]. Given the frequency of VCD reported in the military population, any abnormality should prompt additional testing to eliminate functional or anatomic glottic abnormalities.
    (c) Full PFT: while obtaining a total lung capacity, residual volume and diffusing capacity are not routinely helpful in determining etiology of lung disease in this population, it may be helpful in selected patients. Full PFT may confirm the presence or absence of hyperinflated residual volume or confirm reduced lung volumes in the presence of borderline restricted spirometry. Given the high prevalence of smoking, a reduction in diffusing capacity may either identify early chronic obstructive pulmonary disease (COPD) or other occult interstitial lung disease when evaluating an older or more senior member of the active military population.
    (d) Impulse oscillometry: this technique uses sound waves to measure central and peripheral airway resistance and reactance. In those patients with normal spirometry, evidence of increased airway resistance with a reduction in resistance post bronchodilator may indicate AHR not evident on spirometry [Blonshine and Goldman, 2008]. This testing is not widely used in most military treatment facilities.
    (e) Other studies: maximal voluntary ventilation may be an optional study to consider with normal spirometry as it may be suggestive of underlying lung disease or reduced fitness if less than 70% of predicted. Maximum inspiratory and expiratory pressures should be measured if diaphragmatic weakness is considered or if the patient has an unexplained restrictive process.

(4) BPT: unless the patient clearly has asthma on the basis of obstructive spirometry with a bronchodilator response or a definite imaging abnormality, BPT should be performed in all military patients as part of the diagnostic evaluation. The current test of choice for most military centers is MCT. While MCT has a high false-positive rate and low specificity, a negative test essentially rules out AHR as the underlying cause for symptoms. Alternative methods include mannitol and eucapneic voluntary hyperventilation, which have a similar diagnostic yield as MCT [Anderson *et al.* 2009]. Exercise spirometry may be used as a screening test for potential exercise-induced bronchospasm but lacks the sensitivity and specificity of the other testing procedures [Eliasson *et al.* 2002].
(5) Exercise laryngoscopy: in the presence of normal spirometry and negative BPT, the next common diagnosis in the military population is VCD [Morris *et al.* 2002]. In this population, exercise-induced VCD is the

most common etiology, although consideration needs to be given to other causes, including psychogenic or irritant related (reflux or postnasal drip). Additionally, the appearance of the glottis and associated structures may indicate the presence of anatomic lesions findings consistent with gastroesophageal reflux disease. We generally perform laryngoscopy pre and post exercise to document differences in vocal cord motion (paradoxical adduction) and glottis appearance post exercise [Morris and Christopher, 2010].

(6) CPET: generally, CPET is reserved for patients in whom the diagnosis is not clear despite imaging and the other testing described above. In an older population, CPET may be helpful in differentiating pulmonary or cardiac limitations to exercise or deconditioning. However, for the younger military population, there is little cardiac disease and the presence of most pulmonary disease can be detected by other testing. Additionally, there are no established reference values for CPET parameters in this population [Sill *et al.* 2009]. Despite these limitations, CPET may provide an estimate of the patient's ability to perform maximal exercise, which is important in determining further invasive testing. It may also clarify the differential diagnosis in the following situations: etiology of the dyspnea is unclear; the severity of dyspnea is disproportionate to testing; deconditioning, psychological factors, hyperventilation, and obesity.

Controversies in evaluation

Several issues have arisen in reference to evaluation of military personnel for evidence of postdeployment lung disease. First, it has been suggested that normal PFTs in the presence of symptoms actually indicates a decrement in pulmonary function as military personnel have supranormal values compared with their civilian counterparts. Published literature on highly trained triathletes and marathon runners only shows a slight increase above predicted normal values [Bousanna *et al.* 2001; Ross *et al.* 2008]. Current research comparing spirometry values between military and civilian personnel shows no increase in supranormal values (9.4% in military compared with 12.4% of nonmilitary). Second, it was further recommended by the 2010 Denver Working Group that surveillance spirometry be conducted in all military personnel pre deployment to have a baseline study for comparison post deployment [Rose *et al.* 2012]. While such an approach is currently being investigated, there are several problems with large-scale surveillance. The use of surveillance spirometry in an asymptomatic population is not recommended by any respiratory health society even for COPD or asthma in the absence of symptoms. When indicated, it is best performed longitudinally to evaluate individual and group changes in respiratory health over time [Occupational Safety and Health Administration, 2011]. The routine use of spirometry can be fraught with overdiagnosis, misinterpretation, technically inadequate studies, and career implications for military personnel [Morris *et al.* 2007]. There would also be a significant number of baseline abnormalities that would require additional evaluation [Vedal and Crapo, 1983]. Before the initiation of widespread screening or surveillance with spirometry, feasibility studies should be performed to assess the predictive value, prevalence of disease, and healthcare resource utilization of such a program.

A final issue is the role of surgical lung biopsy in military personnel for postdeployment dyspnea. Surgical lung biopsy has not previously been recommended in the absence of PFT or CT findings and would not typically be performed in nonmilitary patients. Evidence is lacking for any increased rate of subclinical lung disease in the postdeployment population. Controversy remains regarding whether patients from the study by King and colleagues actually have the clinical syndrome of CB as the majority lack evidence of significant airway obstruction on spirometry or characteristic CT findings [King *et al.* 2011]. Pulmonologists within the DoD or VA healthcare systems do not advocate surgical lung biopsy in the absence of PFT or CT findings, or without a comprehensive evaluation to eliminate other causes of disease [Zacher *et al.* 2012].

Current research

Several clinical studies are being conducted at San Antonio Military Medical Center. A comprehensive review of all pulmonary cases in the DoD is ongoing to evaluate the relationship of deployment to common pulmonary conditions such as asthma, COPD, and sarcoidosis. This review does not suggest any overall increase in respiratory disease related to deployment [Rawlins and Morris, 2012]. The Army is also

maintaining a registry for military personnel with pulmonary conditions potentially related to deployment and is actively collecting longitudinal data on enrolled patients. Additional studies include pre- and postdeployment spirometry in soldiers from Fort Hood, TX; evaluating the utility of screening spirometry in new military recruits; and a more comprehensive evaluation of postdeployment dyspnea in all patients with new-onset symptoms. This active clinical research program is being jointly conducted with the VA to evaluate pulmonary disease in the DoD population, and further evaluate links to deployment-related exposures.

Conclusion

At present, toxicological, epidemiological, and clinical data are not adequate to reliably evaluate the prevalence or severity of adverse effects of inhalational exposures to PM or burn pit combustion products in military personnel deployed to SWA. The current clinical evidence on the effect of deployment on respiratory health is primarily retrospective in nature and does not provide any clear information on specific causative factors or the effect on the deployed population as a whole. Continued emphasis should be placed on diagnosing and treating common disorders such as asthma, exercise-induced bronchospasm, and VCD. The VA and DoD, along with civilian medical centers, are continuing to respond to service members' health and wellness needs by evaluating the possibility of deployment-related pulmonary disease in SWA in a comprehensive and scientific manner. To date, there has not been a uniform or single entity found in the evaluation of postdeployment dyspnea that warrants specific or unique therapeutic intervention. While current evidence for deployment-related lung disease is lacking, and a definitive link to specific exposures has not been established, military personnel with postdeployment respiratory symptoms should continue to receive a robust pulmonary evaluation.

Authors' note

The opinions in this manuscript do not constitute endorsement by Brooke Army Medical Center, the US Army Medical Department, the US Army Office of the Surgeon General, the Department of the Army, Department of Defense, or the US Government of the information contained therein.

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