Respiratory Disorders Following Service in Iraq

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Introduction

Over 2 million United States service members have been deployed to the Middle East since 2001, including Afghanistan in 2001 (Operation Enduring Freedom, OEF) and Iraq in 2003 (Operation Iraqi Freedom OIF). Service members participating in each conflict experienced a variety of inhalational exposures. Some exposures such as dust storms were related to climate and location. Other exposures such as battlefield smoke, burn pits, oil fires, diesel exhaust and more were common to all who were deployed. There were still other exposures that were unique to specific countries, regions and events. These unique exposures may have been limited in duration and scope but in some cases affected large numbers of service members.

Inhalational exposures in Iraq and Afghanistan have received a lot of attention due to the number of troops involved and a high incidence of respiratory complaints linked to service. Respiratory complaints were common among service members deployed to Iraq as part of Operation Desert Storm in the 1990s and more recently in soldiers returning from Iraq and Afghanistan. Epidemiologic studies in the United States, England and Australia have documented an increased incidence of respiratory disorders in soldiers who served in the Middle East as compared with soldiers who were deployed elsewhere and an increase in respiratory symptoms associated with service inland versus sea. [1,2,3,4,5,6]

Surveys of soldiers returning from OEF/OIF estimate that 69% of personnel develop respiratory symptoms with deployment.[7] A large number of deployed service members experience cough shortly after arriving in the Middle East. These early symptoms have been characterized as the "Iraqi crud" and are usually self-limited. There are many reports of service members having more sustained disorders including bronchitis, shortness of breath, asthma, eosinophilic pneumonia, and small airways disease. [1,2,5,7,8,9,10] While some service members develop respiratory disorders during deployment, a large number become symptomatic following deployment. [2,10] This is important to note, because military and civilian providers may not link late symptom onset to exposures in theater.

Al-Mishraq Sulfur Mine Fire

Twenty thousand soldiers from the 101st Airborne from Ft. Campbell, KY and other units were deployed to Northern Iraq as part of OIF in early 2003. Several months into their deployment the nearby Al-Mishraq Sulfur Mine caught fire. While Iraqi governmental organizations and others contend that this was a terrorist event, others, including the US Department of Defense, believe that it may have ignited spontaneously.

The Al-Mishraq Sulfur Mine is a state run company associated with the largest sulfur deposits in the world. It is located 45 KM south of Mosul, a city with 1.7 million

residents, and 25 KM northeast of Camp Q West where soldiers from the 101st Airborne and others had been deployed. The plume was detected and tracked by NASA'S earth monitoring Terra and Aqua satellites.

The mine had built up huge stockpiles due to ongoing production and a UN trade embargo on Iraq. The fire resulted in the largest man made release of sulfur dioxide (SO_2) in history. It has been estimated that it released an average of 21,000 tons of SO_2 a day for 30 days, a total of 600,000 tons. (11) In comparison, the 1980 Mount Saint Helens volcano eruption released more SO_2 but over many months, not the one month associated with this event.

Extinguishing the Al-Mishraq Sulfur Mine fire presented risk to both civilians and military personnel. Sulfur fires, like the Al-Mishraq fire, release both hydrogen sulfide (HS) and ($S0_2$). HS is a noxious gas with an odor compared to rotten eggs. Exposure causes neuromuscular weakness, and in severe cases, ventilatory failure. Its effects are felt to be reversible once the exposure has ended. SO_2 is more toxic and has an odor of burning matches. It is a potent pulmonary toxin capable of inducing upper airway irritation, asthma and permanent scarring of the lung. (12)

The health effects of SO_2 exposure can manifest at the time of exposure or long after. Acute effects include airway irritation, cough, shortness of breath and wheezing, with asthmatics being particularly sensitive. Chronic effects of SO_2 exposure include reactive airways dysfunction syndrome (RADS), chronic obstructive pulmonary disease (COPD), constrictive bronchiolitis and increased asthma sensitivity. (10,12)

The US Army collected limited random air samples during the fire. Over 50% of the 32 samples were above the Army's maximal standard of 13 ppm with concentrations as high as 120 ppm being recorded. (16)

There is little published data regarding the effects of the Al-Mishraq Sulfur Mine fire on the civilian population. Most residents in Mosul were in the path of the fire's plume and the exposure in the area has been referred to as catastrophic in intensity. Two local residents died from the exposure and many were treated in local hospitals. It has been estimated that the fire resulted in the loss of $40 million in crop damage and that almost all vegetation within 25 KM died. Hospitals reportedly saw a large number of symptomatic patients but little else is known.

Most of the soldiers from the 101st Airborne returned from Iraq in 2004, one year after deployment. A group of those returning to Ft. Campbell complained of increased dyspnea (shortness of breath) on exertion and an inability to complete a two-mile run within regulation time, one of the parameters used by the US Army to determine physical readiness testing. All of the soldiers returning with exercise limitation met Army readiness standards at the time of their 2003 deployment. Ft. Campbell's Blanchfield Army Hospital evaluated the soldiers with standard cardiopulmonary testing. The evaluations failed to reveal a specific cause for their exercise limitation.

Constrictive Bronchiolitis

Ft. Campbell began referring patients with exercise limitation to Vanderbilt University Medical Center in 2004. Vanderbilt providers were aware of the increase in respiratory complaints, such as asthma, associated with Operation Desert Storm in 2001[1,2,3,4] and a report of eosinophilic pneumonia associated with OIF in 2003-4.[9] The patients referred to Vanderbilt, however, did not seem to have asthma and did not fit the pattern of eosinophilic pneumonia.

Those referred to Vanderbilt with unexplained exercise limitation underwent more extensive testing with chest radiographs, high-resolution computerized tomography (HRCT), full pulmonary function testing (PFT) and cardiopulmonary exercise testing (CPET). For most patients, these studies returned normal or near normal results and failed to identify the cause for their exercise limitation.

Approximately one half of the 120 soldiers referred underwent thoracosocpic lung biopsy to better understand the cause for their limitation. It is unusual to consider surgical lung biopsy in the setting of normal chest imaging and normal physiologic testing, but the majority of the soldiers had been deployed as elite athletes and were now incapable of completing a two-mile run within regulation time. The Army considered them as non-deployable and the soldiers were facing medical board evaluations (military discharge) or early retirement due to exercise limitation.

The surgical lung biopsies appeared to provide an explanation for the soldier's exercise limitation. The majority of biopsies showed abnormalities in the small airways characteristic of a condition known as constrictive bronchiolitis. The pathologic characteristics of constrictive bronchiolitis include thickening in the walls of the small airways with the result of airway narrowing. In most cases the remaining portions of the lung parenchyma appeared normal. The pathologic characteristics of constrictive bronchiolitis were subtle and potentially overlooked if not examined by trained pulmonary pathologists.

Constrictive bronchiolitis is usually associated with clinical states such as organ transplantation, rheumatoid arthritis and rarely occurs in otherwise healthy and athletic individuals. It is known to result from toxic inhalation, with SO_2 being one of the most notable exposures linked to the disease. Constrictive bronchiolitis is not curable and is a progressive disorder in most situations. Most of the soldiers diagnosed ended up being medically discharged from military service due to their inability to meet Army physical testing standards. None of those diagnosed regained their exercise capacity and remain symptomatic with exercise limitation, cough or chest tightness.

There was an initial suspicion that the sulfur mine fire was the only cause for constrictive bronchiolitis, as all of those initially diagnosed had been in the region of the fire. Over time, however, more and more soldiers presented with exercise

limitation having never been exposed to the fire. Vanderbilt investigators performed similar evaluations in this group and found that they too had constrictive bronchiolitis. Currently, Vanderbilt has diagnosed 52 soldiers with constrictive bronchiolitis with over half having only the usual exposures found in theater and no exposure to the sulfur mine fire.[10] Other institutions, such as National Jewish Hospital in Denver, CO have seen a similar pattern in service members.

The diagnosis of constrictive bronchiolitis did not lead to significant change in therapy but did provide an explanation for symptoms. More importantly, soldiers diagnosed with the disorder received disability benefits that would not have been available without biopsy. Soldiers who have unexplained exercise limitation and do not undergo biopsy typically do not receive a rating for their disorder unless another label such as asthma is applied.

The majority of service members diagnosed with constrictive bronchiolitis left military service with a disability rating or retirement and only a few continued to serve in non-combat capacities. Those followed up at Vanderbilt continue to experience exercise limitation, and in some cases demonstrate progression. Follow up chest radiographs, HRCT and PFTs generally remained stable, but the long-term implications of the condition are unknown. The Veteran's Administration has recognized constrictive bronchiolitis as being associated with service in the Middle East. They will inherit the responsibility for following this population and monitoring disease progression. The Social Security Administration recently added constrictive bronchiolitis to its compassionate allowances list, a designation that will help those applying for benefits.

Common Inhalational Exposures

Soldiers serving in Iraq and Afghanistan experienced a wide spectrum of inhalational exposures. While some exposures such as the Al-Mishraq sulfur fire offered an explanation for some, many of those returning had respiratory symptoms that were not linked to a specific event. The list of exposures is extensive and includes dust, burning solid waste, burning human waste, battlefield smoke, industry, oil fires, vehicle exhaust and more. It has been difficult to scientifically connect exposures with specific respiratory disorders.

Dust

Service members arriving in Iraq notice the striking prevalence of dust. Dust is everywhere and on everything. With regularity, individuals experience suffocating and blinding dust storms. Such incursions necessitate suspension of all outdoor activity and require personnel to retreat in-doors and or wear respirator masks. Dust and dust storms pose significant health risks for civilian and military personnel and appear to be getting worse with time due to environmental practices such as reduced vegetation, reduced river and lake water and heavy military traffic dating back to the 1990 Gulf War.

The dust in Iraq is composed of a silica core encased in a calcium carbonate. Dust particles are small enough for dozens to fit on the head of a pin and they contribute to high levels of particulate matter, measured in parts per million (PPM). Department of Defense data have shown dangerously high levels of particulate matter corresponding to 2.5 micron particles ($PPM_{2.5}$) and 10 micron particles (PPM_{10}). The upper respiratory tract does not effectively filter particles this small and they can easily reach the small airways of the lungs.

Elevated $PPM_{2.5}$ and PPM_{10} are associated with an increase in respiratory and cardiovascular disease, disorders which have a higher than expected prevalence in service members. In addition, small particle dust appears to bind bacteria, fungi and toxic biologically active metals. There is speculation that fine particulate matter effectively enhances delivery of such toxins into the small airways of the lung. Almost all patients diagnosed with constrictive bronchiolitis have evidence of dust inhalation. Ongoing research by National Jewish Hospital in Denver, CO, Vanderbilt University and the US Geological Survey is examining the composition of the particulate seen in the biopsies.

Burn pits

Burn pits were used extensively to dispose of both solid waste and human waste in both OIF and OEF. Such practices were unavoidable in the initial phases of combat but there were concerns that this means of solid waste disposal went on for too many years and that there should have been more of an effort to bring in solid waste incinerators earlier. Incinerators burn waste at much higher temperatures, provide more complete combustion and have cleaner emissions than open air burn pits. Kellogg Brown and Root (KBR), a subsidiary of Halliburton Corporation, was responsible for building and maintaining the burn pits in both Afghanistan and Iraq and did not begin to convert to incinerators until Congress encouraged the Defense Department to do so in 2009. [15] Burn pits were often located near living quarters and burned all generated solid waste including toxic materials such as batteries, tires, plastics, etc.

Service members complained about burn pit exposure and felt that their health problems may be related to this exposure. Their complaints and the ensuing wide publicity led the Veterans Administration to ask the Institute of Medicine (IOM) to review the issue. Its study, focusing on the theater's largest burn pit at Joint Base Balad, Iraq, was released in October 2011. It has been difficult to scientifically connect exposures with specific respiratory disorders. The IOM concluded that they could not find evidence of adverse health effects from individual burn pit toxins but that the possibility of combined exposure was a concern. They criticized the data collected by the Department of Defense noting incomplete identification of toxins, the absence of monitoring during heavy burning, inconsistent methods of analysis and poor data regarding military personnel in close proximity to burn pits.[14]

Others

Deployed personnel had exposure to many other inhalational toxins including oil fires, unregulated industrial pollution, vehicle exhaust and combat smoke. It is difficult to know how each of these may have contributed to respiratory disease, but such exposures are commonly encountered during deployment and represent potential inhalational toxins.

Controversy

Most representatives of the DOD, VA and academia agree that there is an increased risk of respiratory disease associated with deployment and that the exposures encountered with recent deployments contributed to the problem. Unfortunately, it has been difficult to characterize the specific exposure or combination of exposures responsible for increased disease or whether some individuals are more vulnerable to specific exposures. For example, it is well established that SO_2 exposure causes constrictive bronchiolitis and that the SO_2 released with the Al-Mishraq Sulfur Mine fire was the largest release in history. It has not been easy to prove that this exposure led to the development of disease in each case in which it occurred.

The DOD issued a memorandum shortly after the fire indicating that $S0_2$ levels, although ten times acceptable limits, did not put service members at risk.[16] A later definitive report issued by the Defense Department referenced limited $S0_2$ sampling and in-theater spirometry with the conclusion that any adverse health effects were likely isolated.[19] The report questioned the finding of constrictive bronchiolitis and suggested that this finding needed validation.

The report associating constrictive bronchiolitis with deployment has been very controversial within the Department of Defense. Representatives of the Department of Defense have questioned the practice of doing surgical lung biopsies and the significance of small airway changes in the setting of normal or near normal non-invasive testing. Representatives of the DOD continue to claim that non-invasive pulmonary evaluations are adequate to screen for disease despite peer-reviewed literature to the contrary.[10,22,23] The DOD no longer refers soldiers with unexplained exercise limitation to academic medical centers with the result that many service members are failing to get appropriate service connected compensation. When asked about this policy, the response has been that the DOD "has a duty to our taxpayers to care for our soldiers within our military health system."[21]

The Veteran's Administration has been more likely to accept a diagnosis of constrictive bronchiolitis and has issued training letters to their providers regarding the potential health effects of being exposed to the Al-Mishraq sulfur fire and burn pits. Despite this acknowledgement, the VA usually assigns low disability ratings to veterans with constrictive bronchiolitis, many of whom would have continued to serve if physically able to do so.

Recommendations

In February 2010, a working group of pulmonologists, occupational specialists, industrial hygienists, the Department of Defense and Department of Veterans Affairs convened at National Jewish Hospital in Denver, CO to discuss inhalational exposures and risk of respiratory disease associated with recent deployments.[20] The group noted the increased incidence of respiratory disease associated with recent deployments, the absence of known specific exposures and the difficulty in identifying specific diseases such as constrictive bronchiolitis following deployment.

Attendees also noted that it was difficult to screen for some conditions such as constrictive bronchiolitis as the usual non-invasive studies were normal. Historical data suggested that symptomatic soldiers with normal or near normal PFTs and CPET would have had better tests had they been evaluated prior to deployment. Representatives from the DOD who attended the meeting attached their names to the recommendations below but simultaneously published a clarification rebutting many of the recommendations.[22]

The group recommended the following. [20]

1. Pre- and post- deployment respiratory questionnaires as well as pre- and post- deployment spirometry. Such questionnaires would document any history of respiratory disease, smoking history, two-mile run times and spirometry prior to deployment.

2. Formal pulmonary evaluations for soldiers experiencing persistent cough, shortness of breath, or an unexplained drop in physical readiness testing. The concern was that the current approach does not follow a protocol and that centers of excellence in respiratory disease may be necessary for this group of soldiers, many of whom may be facing discharge due to exercise limitation

3. Surgical lung biopsies when appropriate.

The National Jewish Hospital meeting primarily addressed the respiratory problems of deployed soldiers but discussed the issue of respiratory health in other populations including civilians in Iraq, and surrounding countries. The group assumed that civilian contractors had the same exposures as US military personnel but acknowledged the absence of data systematic follow up for this population.

Conclusion

Military deployments present challenges to service members both on and off the battlefield. Those deployed are primarily challenged by the mission at hand and are

required to maintain a focus on completing their missions effectively and safely. It is clear, however, that despite planning and preparation, every mission will encounter unanticipated challenges including illness. Conflicts dating back to Viet Nam have produced new health concerns with new exposures, syndromes and diseases linked to specific conflicts. Agent Orange, Gulf War Syndrome, post traumatic stress disorder, traumatic brain injury, suicide and constrictive bronchiolitis are a few that have been linked to specific engagements.

Data already exists to suggest that respiratory disorders associated with deployment present many challenges for both soldiers and the providers caring for them. We need to assume that service members will experience exposures, some of which are preventable. We also need to be concerned that the respiratory issues described with US service members may apply to other populations such as civilians, the tens of thousands of contractors deployed to the region and those who served in surrounding areas such as Kuwait and Saudi Arabia.

Respiratory function must be assessed before deployment and regularly thereafter. Experiences with recent conflicts suggest that respiratory disorders may be added to the list of unseen disorders following service.

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