6-2014

From Sea to Shining Sea: Force Health Management of Infectious Diseases in a Cross-Global Deployment Flux toward Tropical Environments

Joanna M. Nelms
Wright State University - Main Campus

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Joanna M Nelms, MD, MPH

Wright State University

June 2014

Dedication

To my husband, Kyle: thank you for putting up with me throughout this process (yes, the bouts of cabin fever, the tortilla incident, and the general freaking out). You are still my best thing. May this research pay tribute to the heroic service of Nelms and Funk family members in the great history of this country's military endeavors.

Acknowledgments

This project could not have reached completion without the patient help from Dr. Nikki Rogers and Dr. James Ebert, who coached, cheered, and critiqued my progress like champions. Thank you for answering my endless questions and emails and for letting me be that "different" student. Additionally thank you to all of the past and present-serving military physicians who took time out of their busy and important lives to answer the questions of one very young and inexperienced flight surgeon. When I grow up, I want to be like you.

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Abstract

Infectious diseases in fighting armies are a pestilence as old as war itself. The history of the United States military is rich in successes of innovation and lessons learned in failure in the prevention and treatment of infectious diseases. Over the nearly two and a half centuries of American warfare, military research and development have contributed greatly to advancements in vaccines, medical treatments, and other control and prevention strategies for tropical and other infectious diseases. Current deployments in desert environments have provided continued research and progress in infectious disease control, treatment, and prevention, despite a relative decrease in civilian medical focus toward the field. In the case of a cross-global flux of US troop deployment resulting in in distribution to more tropical locations, the military will need to transition the current system of deployment planning in order to prepare. While the large-scale deployment planning structure is secure, changes will need to be executed in force health management education among military members, civilian support systems, and the public health community. Additionally, there will be some environmental and diseases-specific concerns to address, and an increased obligation for biowarfare awareness and counter planning. Execution of this transition will provide for optimal force health management and protection for American warfighters across the globe.

Keywords: force health management, deployment medicine, tropical diseases, infectious diseases, military history, disease control and prevention

> More than one great war has been won or lost not by military genius or ineptitude, but simply because the pestilence of war – from smallpox and typhoid to cholera, syphilis, diphtheria, and other scourges – reached the losers before they infected the winners.
>
> Allan Chase, *Magic Shots* (1982, p. 197)

From sea to shining sea: Force health management of infectious diseases in a cross-global deployment flux toward tropical environments

Since antiquity, infectious disease has been known as the scourge of war. Even the earliest civilizations record non-battle deaths due to infection and disease. In the Iliad, Homer paints the description of “deadly pestilence”; and while fictional, the work is largely believed to be based on true events. Disease burden in military conflict has persisted down through the ages of the Greek and Roman empires, the rise and fall of European powers, and into the relatively short lifetime of the United States (US) military. In 1916, Freidrich Prinzing coined the term ‘war pestilences’: a grouping of common wartime diseases including diarrheal diseases, smallpox, typhus, and plague. Along with these, Prinzing noted that sexually transmitted diseases (STDs) such as syphilis “followed at the heels of belligerent armies” both deployed and in garrison (Short, 2010, p. 16). Infectious disease and warfare are indeed inseparable.

Not only has infectious disease burden followed military conflict and civil unrest over time, but these hostile engagements have increased in frequency and duration (Smallman-Raynor & Cliff, 2004). Since the end of World War II, over 350 wars, revolutions, or other bouts of civil unrest have erupted across the globe (Short, 2010). Not only are these conflicts increasing in frequency but they also occur increasingly in countries with lower socioeconomic status and are waged more and more often by non-government entities (Short, 2010). Civilian populations in these nations are then not only affected by the traditional issues of becoming or interacting with displaced persons, destruction of villages and land, and disease. Modern wars and civil unrest notoriously disrupt higher-level aid programs and government structures, halting federal and international efforts at disease control. In short, the disease burden caused by military conflict is not reserved to the armies themselves, nor is it spread solely by their presence.

All persons traveling internationally are at increased risk for infectious diseases when compared to the common population (Bacaner, Stauffer, Boulware, Walker, & Keystone, 2004). In civilian populations, travel-related morbidity is most commonly linked to infectious disease. Of these infectious diseases, the most commonly noted are diarrheal diseases, malaria, and vaccine-preventable infections (Keystone, Kozarsky, Freedman, Nothdurft, & Connor, 2008). Militaries are a unique breed of international traveler in that they have a predetermined susceptibility to infectious disease outbreaks (Hoyt, 2006). The frequent and rapid changes in geography (for both trainings and war deployment), mixed with stress, exhaustion, and wounds creates the perfect framework for disease propagation. Camp conditions, long cited as reasons for outbreaks in military populations, allow for mixing, mutation, and fast spread of infectious agents (Hoyt, 2006). The types of infectious diseases seen in armies are similar to those experienced in traveling civilian populations, but the conditions of military travel and lodging often create the increased detriment.

Until World War II, more US military personnel died in wars from infectious diseases than enemy battle action (Cirillo, 2008). In his work on disease effects on major US military conflicts, Cirillo describes the ‘Disease Era’ of the American military and its transition into the ‘Trauma Era’ particularly over the watershed decades (1930-1950s) when vaccines and antibiotics emerged in force. Despite many shortfalls and ‘lessons learned’ along the way, the

US military has contributed heavily to innovation in the control, prevention, and treatment of infectious diseases over the past two centuries (Hospenthal, 2005).

As world political climates change, the US military must constantly look ahead to the next potential threat. The past three decades of large-scale American military involvement have been in desert regions, predominantly in southwestern Asia. In the event of a cross-global flux of troop deployment resulting in increased involvement in more tropical regions (e.g. the Pacific, southeastern Asia, and tropical Africa), several transitions will be necessary within the purview of force health management in order to best protect America's military assets. In this transition, tropical and infectious diseases will pose a definitive threat toward American force health protection.

Traditional medical research on infectious disease spread tends to focus on the hospitalized patient and not the environment of disease transmission (Dorogi, 2009). To effectively control and prevent infectious disease in the military deployment setting, it is imperative to use epidemiology and environmental health evaluations to critically evaluate the setting. Because of the high and detailed levels of health data collection the military can produce, their surveillance and research on infectious diseases and their treatment is paramount. This research will not only improve the quality of military force health but can also fill the gaps in some of the civilian data for tropical diseases (such as dengue fever) (Sebeny & Chretien, 2013).

History is well known to repeat itself. Understanding the history of past successes and failures of force health management is vital to providing excellent care in the future. In addition, collaboration needs to occur between not only the branches of the US military, but also between the Department of Defense (DoD) with the academic and industrial communities. These partnerships will allow better tracking, control, and prevention of infectious disease outbreaks.

'Cross-culture' education between civilian and military practices will not only enhance force health protection but also can play an important role in provision of humanitarian aid (Wilson, Truesdell, & Rinaldo, 2005). Thus efforts toward American force health protection not only function to unite highly effective teams among the medical and public health communities but also can provide a global benefit to disparate populations.

The current literature describes many facets of the history and current practices of force health protection and military infectious disease control. However, there is relatively less literature focused on synthesizing these findings and projecting towards further needs and objectives to manage these fields on a military-wide level. This research is particularly crucial as the US military may experience a cross-global flux into new locations, specifically more tropical climates, in the future. The delineation of any paradigm shifts in force health management that would be needed remain undetermined to date.

Statement of Purpose

The purpose of this research was to conduct a historical review of force health management during US military conflict over the past century, focusing specifically on prevention, control, and treatment of infectious diseases. By using historical lessons learned, understanding current problems in deployment medicine, and referencing current medical and public health recommendations, necessary transitions can be identified for US force health management to undergo in preparing and protecting a force flux from the deserts of the southwest Asia to more tropical climates.

Methodology

This research was accomplished through a literature review on historical deployment health and disease issues in military conflict. The primary variable of interest in this review was the role played by infectious diseases in wars throughout history, focusing on the participation of the United States military in conflicts. By analyzing this information, the shortfalls and corrections of military public health and force health protection were identified as 'lessons learned' during these conflicts. Secondarily, the diseases of tropical climates themselves were identified and researched, with the prospect in mind that the United States military may return to more tropical deployment environments after this current long stint of service action in the desert climate of southwest Asia.

A large portion of the literature search was conducted via the MedLine database for scholarly articles pertaining to military epidemics, tropical disease, and deployment medicine topic areas. The search was not limited by dates of publication. Articles without full text in English were omitted from the review. This material was compiled and sorted to create a basic timeline of United States military disease burden throughout history. This timeline provided a traceable path of the 'lessons learned' and provided grounds for projecting future threats and needed transitions in force health management that the US military may face in coming conflicts and deployments.

Research on the tropical and travel diseases was conducted largely though MedLine searches as well as the traditional travel medicine and diseases provided on the Centers for Disease Control and Prevention (CDC) website (CDC, 2014). In addition to traditional literature review, a review of online lecture series and podcasts allowed for more current and personal data collection. The vast majority of these lectures pertained to tropical and travel medicine and epidemic diseases. These data were used to create a best practice framework of current standard of care for the tropical and infectious diseases that the US military may face in future deployments. This framework provided a basis for the suggested adjustments that will be needed in US military force health protection in the situation of a shift to more tropical deployment environments.

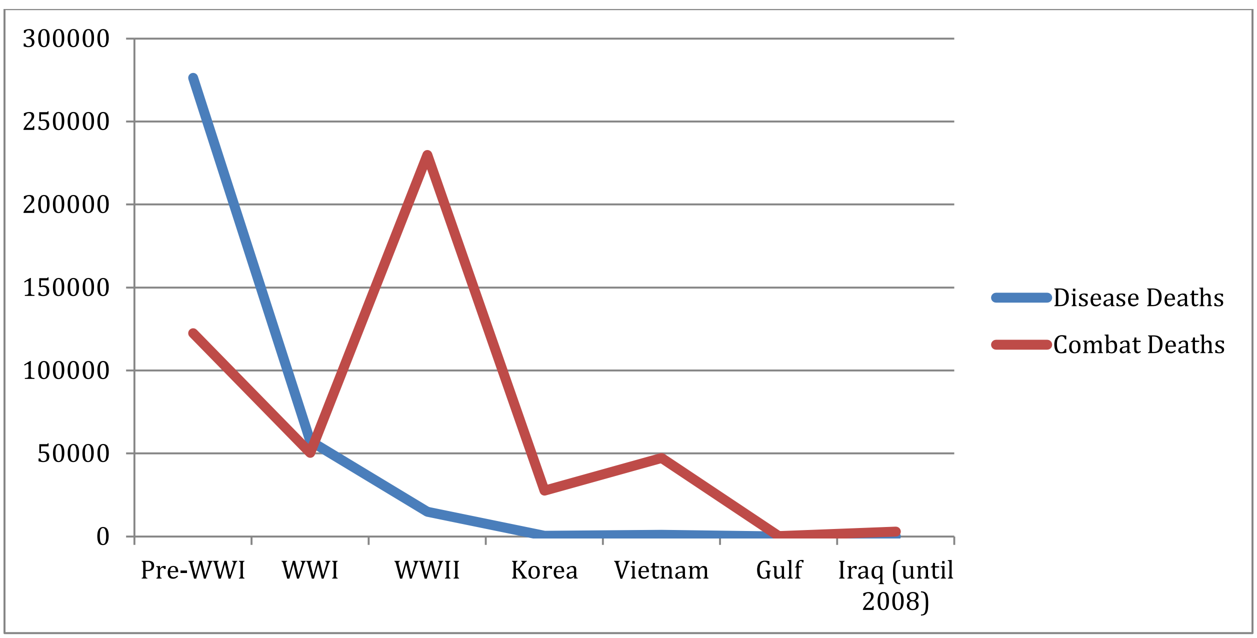
To supplement this literature review, a short questionnaire was distributed to a set of six military physicians (both active duty and retired) who have served on a variety of international fronts (see Appendix A for physician listing and Appendix B for questionnaire). The supplement of their personal experiences, findings, and anecdotes enriched the literature review. These personal accounts also provided a clear picture of issues in some of the most recent US deployment situations. Their rich and extensive knowledge of the workings of US military force health management provided suggestive guidance toward areas of force health management areas requiring future improvement. The survey method was deemed to be outside of the realm of human subject research and it was IRB exempt (see Appendix C). The opinions expressed by these individuals were given freely under full disclosure of the purpose of this research and without compensation of any kind. The opinions and anecdotes expressed by these individuals reflect their personal accounts, thoughts, and feelings and are not an official representation of the Department of Defense or United States military in any official context.

Literature Review

Disease and the United States War Machine: A Historical Review

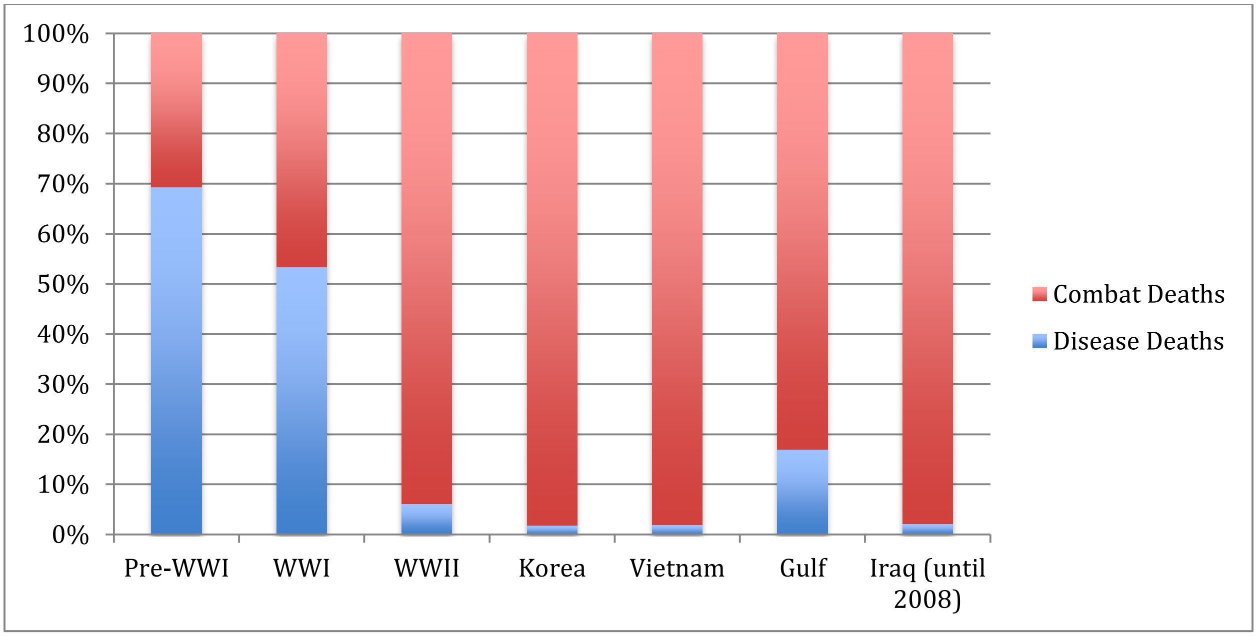
Infectious diseases claimed more US military lives than combat in every conflict from the American Revolution until World War II (WWII) (Cirillo, 2008). This pattern of deaths by disease versus combat-related injuries for major US military conflict periods is shown in Figure 1. While this graph is useful for tracking the general decline in total US military deaths over time, it does not clearly show the relationship between combat-related injury deaths and those from infectious diseases. A comparison death percentages from disease versus combat-related injuries better demonstrates the effect of the epidemiologic transition affecting US troop deaths in conflict over the past two and a half centuries (Figure 2).

The transition of the so-called 'Disease Era' into the 'Trauma Era' occurred following World War I (WWI) and in conjunction with the American epidemiologic transition of the early 20th century. This shift was heavily associated with the developmental swell of vaccine and antibiotic innovation. This time period produced an era of declining pandemics and general decrease of infectious disease-related morbidity and mortality in the US population as a whole (Omran, 1971). The population-wide decreases in morbidity and mortality from infectious disease were echoed by the military rates during the 20th century. The notable exception to this general progression is seen in the data on disease deaths in wars of the latter century, specifically the Gulf War era and the Iraq War. This inflation is due to the relatively small numbers of total casualties in these conflicts as compared to previous wars (as seen in Figure 1).



*Pre-WWI: Revolutionary, War of 1812, Mexican, Civil, Spanish-American, and Philippine Wars
** Source: Cirillo, 2008, p. 123, Table 1

Figure 1. Total deaths from disease and combat injuries in US troops in major military conflicts.



*Pre-WWI: Revolutionary, War of 1812, Mexican, Civil, Spanish-American, and Philippine Wars
** Source: Cirillo, 2008, p. 123

Figure 2. Percentages of deaths from disease versus combat injuries in US troops in major military conflicts.

Despite many shortfalls and 'lessons learned' along the way, the US military has contributed heavily to innovation in treatment and prevention of infectious diseases over the past two and a half centuries. The following sections of this text serve to provide a review of US military medical history, those lessons that were learned, and the innovations that resulted.

Pre-WWI.

Prior to World War I (WWI), infectious disease was the major player in US military deaths. Smallman-Raynor and Cliff (2004, p. 182) classified the critical disease groupings of this era of military conflicts into the following:

- Venereal diseases
- Fevers (including poxes, hemorrhagic fevers, malaria, measles, etc.)
- Constitutional diseases (e.g. tuberculosis)

- Local diseases (e.g. respiratory infections and pneumonias)
- Nervous diseases (including delirium tremens, all general PTSD-like conditions, and shell-shock)
- Dysentery (including cholera and other diarrheal disorders)

As the historical discussion of military infectious diseases continues through this manuscript, these generalized disease groups resurface repeatedly.

In after-action reports, smallpox was cited as a major factor in the failure of the Continental army attempt on capturing Quebec during the American Revolutionary War (Hoyt, 2006). The toll was great enough that in 1777 General Washington mandated that all enlistees of the Continental army be inoculated with smallpox (Cirillo, 2008). Outbreaks of dengue fever were noted among troops stationed along the shorelines of the Delaware river in 1780 (Endy, Thomas, & Lawler, 2005). Camp sanitation was so poor at the time that Washington also mandated his field officers to enforce adherence to principles of Mosaic code (found in the book of Biblical book of Deuteronomy). The code included regulation of outhouse placement certain distances away from the camp and food storage guidelines, among other restrictions (Lim, Murphy, Calloway, & Tribble, 2005). While the code was ancient even in Washington's time, the principles therein are basic pillars of public health seen in modern times. Despite his insistence on suitable disease control and prevention, General Washington regrettably died as a result of bloodletting, the standard accepted medical treatment of the day for respiratory disease (Ottolini & Burnett, 2005). (It is estimated that the founding father underwent four serial lettings, totaling in a volume of greater than 70 ounces, on the day of his demise.) Washington's untimely and ironic death at the hands of the healthcare community only stands to reiterate that without a marriage of good public health and medical principles, unnecessary infectious disease deaths will only continue.

Diarrheal diseases and dysentery were scourges of the American Civil war (1861-1865) (Mostofi, 1968). In Margaret Mitchell's (1936) classic, *Gone With the Wind*, Mammy attests that there wasn't a sound set of bowels in the entire Confederate army and that this condition resulted in their defeat (p. 501). Measles were also a problematic source of troop morbidity and mortality during the American Civil war (Ottolini & Burnett, 2005). These camp outbreaks frequently spread quickly and claimed heavy tolls on troops. Smallman-Raynor and Cliff (2004) summarized the work of E. Steiner's 1977 study to report the following causative factors toward the outbreaks:

- Military enlistment of active and contagious disease carriers
- Troop enlistment and transport to camps during disease incubation
- Disease contraction from infected or carrying medical personnel
- Use of ill recruits in kitchen, hospital and sanitation roles in the camps
- High virulence and attack rate of the disease
- General low diseases resistance in recruits (Smallman-Raynor & Cliff, 2004, p. 191)

These major causes of these camp outbreaks of measles can be reasonably extrapolated to other infectious diseases during the American Civil war and other eras of warfare. Military camps were (and are arguably still) textbook breeding grounds for epidemics, given their crowded conditions, sanitation, and the general morale and stress levels of their inhabitants.

The Union created the Army Medical Department in 1818 in hopes of improving medical knowledge among military physicians (Ockenhouse, Magill, Smith, & Milhous, 2005). However at the onset of the Civil war, camp conditions were deemed so poor that the Commission to

Study and Advise on Sanitation in the Army was formed in 1861 to reform the struggling Army Medical Department. A major advance from this formation was mandatory filing of monthly sickness and wounded reports form all Union regiments. Death counts from both dysentery and measles were improved in part by sanitation mandates, despite lack of antibiotic treatment (Mostofi, 1968; Ottolini & Burnett, 2005).

Despite the attempts of the Army to improve, ‘camp fevers’ (typhoid, malaria, and ‘typhomalarial fever’) were endemic to this era (Cirillo, 2008). The Spanish-American War (1898) was notable for some of the worst known typhoid fever outbreaks in American military history. In the Mexican War (1846-1848), for every one death from injury, there were seven deaths from disease - predominantly dysentery (Lim et al., 2005). It is estimated that 96.8% of non-battle-deaths during this conflict were attributed to diarrhea and other ‘camp diseases’ alone (Cirillo, 2008). These sizeable setbacks were mitigated partially with improvements in camp hygiene, but without definitive treatments or prevention of these infectious diseases, the forces suffered great losses of manpower. As military hygienist, Alfred A. Woodhull noted in 1909, “the sick are for the time as ineffective as the dead” (Cirillo, 2008, p. 125). Decreasing mortality to some infectious diseases of the time failed to address the morbidity these diseases executed on the troops.

Despite gaps in general understanding and archaic standards of care for infectious diseases in this era, some notable advances in force health protection did occur, particularly in malaria research. By the time of the Civil war, quinine had been accepted as a treatment for malaria and was gaining popularity as a preventative medication (Ockenhouse et al., 2005). Major Walter Reed debunked the concept of typhomalarial fever in 1878 resulting in focus drawn more to the research of malarial strains. Major Reed also worked heavily with the Yellow

Fever Commission during this era in creating a foundation of research on the disease (Endy et al., 2005). Colonel William Gorgas conducted malaria research in conjunction with the Panama Canal projects in the early 1900s. He founded four major suggestions for malaria mitigation.

- Eliminate mosquito breeding sites with draining of swamps and spraying oils;
- Employ mosquito “swatters”;
- Install screens on living quarters;
- Distribute quinine prophylaxis.

These four principles, when enacted, resulted in decreases of malarial cases from 800 out of every 1000 workers to 10 cases out of every 1000 (Ockenhouse et al., 2005). This first emergence of study of the ‘tropical diseases’ would serve the US military and future medical research well in the coming years.

WWI.

World War I marked the closure the ‘Disease Era’ of American military history, but not without significant failures and lessons learned (Cirillo, 2008). The Germ theory was increasing in popularity within the scientific community, and with it came sizeable improvements in public health and military force health management.

Typhoid fever continued to play a large role in military disease concern (Mostofi, 1968). The US military was the only one of the seven major world powers to dictate mandatory typhoid and paratyphoid vaccination for military recruits, leading to US troop advantage over the enemy during WWI. Body lice were found to be the probable cause of the spread of trench fever, and prompting suggested deterrence methods for troops in the trenches (Byerly, 2010; Mostofi, 1968). Thousands of cases of leishmaniasis were documented but without a good definitive treatment regimen (Crum, Aronson, Lederman, Rusnak, & Cross, 2005). On the whole, vector control was poor during this era, despite the effective recommendations of Colonel Gorgas only a few years prior (Endy et al., 2005).

Respiratory diseases like measles continued to flourish in the crowded barracks (Ottolini & Burnett, 2005). However, the most notable of the WWI disease outbreaks was the influenza (flu) pandemic of 1918. Estimated worldwide deaths ranged between 20 and 50 million (Hoyt, 2006). This worldwide pandemic in the chaos of a worldwide war resulted not only in a huge toll on human life, but also on significant research commitments to study infectious respiratory diseases. The US military was at the forefront of this research. The War Department's conservative count estimated 26% of the army to have contracted the disease and tens of thousands to have died from it and the associated pneumonias (Byerly, 2010). In 1918 alone, Naval hospitals admitted over 120 thousand sailors and marines, over 4,000 of which died as a result of the disease (Naval History and Heritage Command, n.d.). The warfront itself was not the only military breeding ground for the virus, as the epidemic spread from camp to camp on American soil. Quarantines were enacted, but often with little effect for disease control (Byerly, 2010).

Out of the darkness of one of the worst pandemics in recorded medical history, the light of innovation still shone. WWI marked the first era of American warfare where vaccines played a major role in disease prevention (for typhus, typhoid, and smallpox) (Byerly, 2010). Military public health initiatives led to testing of drinking water and employment of basic water purification techniques. Military force health protection and the medical community as a whole were not prepared, though, for the onslaught that could so rapidly occur with influenza or other pandemic diseases. This catastrophe intensified the push toward infectious disease control and prevention.

WWII.

The time surrounding World War II and the American military transition to the ‘Trauma era’ of warfare medicine could be considered the watershed period of infectious disease prevention, control, and treatment (Cirillo, 2008). Sir William Osler (1915) noted several years afore that, “Science is the best friend war has ever had; it has made slaughter possible on a scope never dreamt of before” (Cirillo, 2008, p 128). In truth, this era of increased research into vaccines, antibiotics, and medical education on tropical diseases ushered in a new era of American warfare. Key improvements stemming from innovations surrounding the WWII era included: fly control in camps, proper disposal of human, animal, and kitchen wastes, development of blood replacement substitutes like plasma, insecticide development and deployment, mandatory troop immunizations for a wider variety of diseases, and mass production of the mighty wonder-drug, penicillin (Cirillo, 2008; Hoyt, 2006). Infectious disease rates fell among military populations, mirrored by the rates in civilian populations (Smallman-Raynor & Cliff, 2004). Thus the United States was ushered into the era of receding pandemics. Tropical and infectious diseases continued to afflict the American military, but the triumphs of medical research and vaccine development would prove to stand as the hallmarks of this time.

Problematic diseases of WWII.

The diseases encountered by American troops during WWII were as wide-ranging as their deployment locations sprawled across the globe. While vaccines and ‘miracle’ antibiotics were becoming increasingly potent and available, infectious disease persisted. However, for the first time in American history, the disease deaths of a war did not outnumber those from combat injuries themselves (Cirillo, 2008).

Malaria continued to plague troops deployed in the Asia- Pacific region (Cirillo, 2008). Despite the effective prevention methods established by Colonel Gorgas and others during the early 1900s, the execution and implementation was left up to line officers. The poor compliance of these officers to implement protective measures with their troops led to a bloom of cases (Ockenhouse et al., 2005). The development and implementation of large-scale insecticide use decreased the case statistics but failed to eradicate the disease in the deployment setting. Vector control failures also contributed to thousands of cases of leishmaniasis from sand fly bites (Crum et al., 2005). Filariasis, a mosquito-borne nematode, was one of the most common reasons for medical evacuation out of the south Pacific. Despite vector precautions, dengue fever raged through the troops in the Pacific where *Aedes* mosquitos swarmed the jungles (Endy et al., 2005). Scrub typhus outbreaks were common in the Burma campaign and other areas of the south Pacific, transmitted by the bites of infected chigger mites (Short, 2010; Smallman-Raynor & Cliff, 2004). Jungles in the Burma-India theater were deemed to be some of the 'unhealthiest' of the war. Diarrheal diseases continued to pose threat to force health in all fighting theaters across the globe (Lim et al., 2005). Overall mortality rates decreased, but the same generalized groups of 'war pestilences' continued to plague the US military throughout the deployments of WWII.

Research triumphs of WWII.

Wartime research programs during WWII led to the development of many treatments and preventative measures for tropical and infectious diseases. Federal support in collaboration with industry and academia fostered a rich and motivated research climate as the country took on a uniform sense of urgency (Hoyt, 2006). The common goal of the nation allowed for a cooperative environment ruled by top-down governance, ensuring that all work focused toward and met military needs. While this notion of science may be repugnant to some modern researches, James Conant (former director of the National Defense Research Committee) commented in a 1945 letter to the editor of *The New York Times*:

> There is only one proven method of assisting the advancement of pure science – that of picking men of genius, backing them heavily, and leaving them to *direct themselves.* There is only one proven method of getting results in applied science – picking men of genius, backing them heavily, and *keeping their aim on the target chosen* (Conant, 1945; Hoyt, 2006, p. 50).

The collaboration across the scientific community allowed for greater accomplishments during this era than any of the individual components (military, academic, or industry) could have created alone (Hoyt, 2006).

At the onset of WWII, the study of tropical medicine was in its infancy, and most American medical schools did not broach the subject (Mostofi, 1968). Fixed medical general laboratories and field medical laboratories were deployed by the Army to better understand what the American troops spread across the globe were exposed to. Setting up research stations in the Asia-Pacific region proved to be difficult, as authorities worried the research efforts would take away from efforts to treat injuries and the military clinical staff was reluctant to report preventative medicine to command. Despite this resistance, implementation of these labs led to the contributions to tropical medicine listed in Table 1 and Table 2.

It is important to note that the Army medical researchers were not the only ones participating in medical research during the war. Naval medical research units (NAMRUs) deployed worldwide to conduct field research on many tropical infectious diseases. While most of the Army laboratories described in Tables 1 and 2 were dissolved after hostilities ended, the NAMRUs have been deployed repetitively throughout other US conflicts following WWII. The contributions from military field research from this era generated a foundation for tropical and infectious disease prevention, control, and treatment that would be built upon for decades to follow.

Table 1. *Contributions of US Army Fixed General Medical Laboratory Units in WWII toward Tropical Medicine*

Medical General Laboratory	Location (Deployment Date)	Contributions to Tropical/Deployment Medicine
1st (General Medical Laboratory A)	England (1943); transfer to Paris (later date)	Studied: scrub typhus, leishmaniasis, shigellosis
15th	Naples (1942)	Studied: typhus, diarrheal diseases, Q fever
18th	Honolulu (1944); detachments to Iwo Jima, New Guinea, Philippines, Okinawa, Saipan, Anguar, Peleliu, Guam, New Caledonia, and Japan (later dates)	Studied: filariasis, schistosomiasis, chlonorchiasis, brucellosis, influenza epidemics, salmonellosis, DDT distribution by aircraft for vector control, bacterial enteric pathogens, epidemic amoebiasis
19th	Philippines (1943)	Studied: schistosomiasis, amoebiasis, other intestinal parasitic diseases, ascariasis, trichinosis, hookworms, scrub typhus, hepatitis, diphtheria, fevers of unknown origin, filariasis, insect vectors

*Source: Mostofi, 1968, p. 708-711

Table 2. *Contributions of US Army Field Medical Laboratory Units in WWII toward Tropical Medicine*

Medical Laboratory	Location (Deployment Date)	Contributions to Tropical/Deployment Medicine
1st	Oran (1943); transfer to Marseilles (later date)	Studied: dysentery, diarrheal diseases
2nd	Casablanca (1942)	Studied: bacterial dysentery, local food and water security
4th	Africa (1943)	Studied: dysentery, malaria, typhoid
7th, 10th, 28th, 361st, and 362nd	European theater; 28th transferred to the Philippines (1945)	Studied: diarrheal diseases, non-tropical diseases
9th and 29th	China-Burma-India theater	Studied: parasitic diseases, development of tropical disease refresher course for technicians
3rd, 5th 6th, 8th, and 14th	Pacific Theater	Studied: malaria, dysentery, filariasis, schistosomiasis, other parasitic diseases
26th (reactivated: 406th Medical General)	New Guinea (1943); transfers to Luzon, Kobe, Kyoto, (later dates); deactivated and reactivated in Tokyo (1946)	Studied: diarrheal diseases, dysentery, scrub typhus, tularemia, hemorrhagic fevers, schistosomiasis, hookworms, paragonimiasis, clonorchiasis, immunologic aspects of viral tropical diseases

*Source: Mostofi, 1968, p. 708-711

Vector control methods for malaria and other arthropod-borne diseases again fell into the spotlight for deployment medicine concern. Because compliance with preventative measures like camp clearing and netting use was left to overtasked line officers, need existed for additional protection (Ockenhouse et al., 2005). The recently developed the insecticide dichlorodiphenyltrichloroethane (DDT) was added to Army supply lists officially in 1943 and was successfully deployed with troops in Italy in 1944. This advancement in chemical insecticide use, through now frowned upon by many environmentalists, proved to be one of the greatest accomplishments in vector-borne disease prevention.

The Army established their Epidemiological Board in 1941 (Ottolini & Burnett, 2005). Eventually this organization became the Armed Forces Epidemiological board, with participation from all US military services. During the WWII era the board was responsible for investigations on pertussis, group B streptococcal infections, and respiratory syncytial virus (RSV). While its function eventually transitioned to a more advisory than expeditionary one, this organization has contributed invaluable research and innovation to the management of force health.

Vaccine innovation explosion.

While medical research surged during the WWII era, no advances were quite as impressive as those in the realm of vaccines. Of the twenty-eight vaccine preventable diseases identified in the 20th century, ten of the vaccines were developed or greatly improved during the WWII era (Hoyt, 2006). These innovations are listed in Table 3, and some of the major achievements are highlighted below.

Table 3. *Vaccine Innovations Produced by US military Research during WWII*

Entirely new vaccines	
	Typhus
	Botulinum toxoid
	Japanese encephalitis
First licensed vaccines	
	Pneumococcal pneumonia
	Influenza
	Plague
Significant improvement to existing vaccines	
	Yellow fever
	Cholera
	Smallpox
	Tetanus

*Source: Hoyt, 2006, p. 39

On the heels of the WWI flu pandemic in 1918, influenza vaccine development continued at the forefront of civilian and military researcher efforts. Dr. Thomas Francis, the commissioner of the influenza commission noted that a “virulent influenza may be more devastating to human life than war itself.” (Francis, 1958, p121).

In the 1930s, the 17D yellow fever vaccine had been released for use (Endy et al., 2005). Despite rare cases of encephalitis as a side effect of the vaccine, the efficacy was impressive and there were no recorded cases of yellow fever in American troops during WWII (Cirillo, 2008; Endy et al., 2005). Prior to 1942, the yellow fever vaccine used human serum and was causative for passing hepatitis B infections to many individuals. The creation of a serum-free vaccine avoided this risk completely (Hoyt, 2006).

Some vaccines were created to function as mission-specific preventative measures (Hoyt, 2006). For example, the botulinum toxoid was created as a combat specific need; US military intelligence believed that the Germans were lacing their rockets with botulinum toxin and prepared the toxoid as a part of D-day preparations. Likewise, the Japanese encephalitis vaccine was developed with the land invasion of Japan in mind.

While the successes of vaccine development were many and significant, failures were also inevitable. The anthrax vaccine program was all-but-squelched due to lack of understanding for the program need and poor scientific understanding of biowarfare (Hoyt, 2006). Industry and academia lost interest in pneumococcal vaccine development after the development of sulfa antibiotics in the late 1930s and their proliferating popularity. Little did the medical community understand at the time what challenges the use of these ‘miracle drugs’ would produce in regards to organism resistance and disease mutation in the future. Thus America entered the age of antibiotics – reliant on their relative inexpensiveness, ease of administration, and general scientific consideration as more effective and safer than vaccines.

Korea and the Cold War era.

The Korean War (1950-1953) garnered US involvement as a part of United Nations support for South Korea. Once again, vector-borne disease caused significant morbidity and moderate mortality in American troops. Despite earlier vaccine innovations, Japanese encephalitis outbreaks occurred repeatedly (Hoyt, 2006; Short, 2010). Numerous cases of filariasis circulated through deployed units (Crum et al., 2005). Malaria cases swelled during and after American troop deployments to Korea (Ockenhouse et al., 2005). Chloroquine, the current standard of care for malaria, was discovered to only kill *Plasmodium vivax* parasites circulating in the blood, neglecting those in the liver. This discovery led to a rapid approval from the Federal Drug Administration (FDA) to use primaquine as a curative agent. When the 14-day regimen was completed in full compliance, the case numbers dropped substantially.

The study of hemorrhagic fevers amplified as case counts climbed and new disease strains appeared (Mostofi, 1968). These arthropod or rodent-borne viruses caused multisite hemorrhage and shock in their victims, most commonly distinguished by bleeding into the skin (Endy et al., 2005). Dengue occurred in troops stationed in Thailand and the Philippines during the conflict. Hantaviruses, spread through the droppings of rodents, were implicated in hemorrhagic fever and renal syndrome (HFRS) (Short, 2010; Endy et al., 2005). Given the nature of the warfare, exposures the soldiers faced, and their risk for contact with rodents (and their excrement), HFRS outbreaks ensued throughout American troop deployments in the war.

Diarrheal diseases persisted as a menace to military forces. Despite an oral vaccine that had exited since the 1800s, cholera remained a significant problem in most of the developing counties of Asia-Pacific (Lim et al., 2005). Untreated fatality rates in the general population during this time were over 60%, and even with treatment 20-30% perished. With affected individuals producing volumes of up to 30 liters of stool daily, even those who did not die were severely incapacitated, damaging not only force strength but also morale. Vaccine field tests unveiled that the old vaccine had poor efficacy and high reaction rates and was generally not cost effective for use. Treatment and control measures, including use of specialized cholera cots and testing of oral rehydration solutions, were established with dramatic improvements in disease mortality. (Further discussion of the military contributions to the treatment of cholera follows in the section on Lessons Learned and Innovations from US Military Medicine).

As the Cold War commenced, biowarfare surfaced as a growing national concern. Throughout the 1950s and 1960s, the American biowarfare program flourished, unknown to most of the nation and the world (Riedel, 2004). Additionally, defensive programs focused on vaccines, antidotes, and cures for possible inflicted biowarfare from enemies. These concerns were not wholly unfounded, as the Soviet Union was later found to have stockpiled filoviruses akin to Ebola and Marburg, among other infectious agents, as a part of their biowarfare program (Endy et al., 2005).

Vietnam.

American military involvement in the Vietnam conflicts overlapped into the Korean War and Cold War eras, spanning from as early as 1950 until peace was declared and American troops were removed in 1973. Vietnam has been a historically harsh and feared location for military action. As early as first century A.D. Chinese documents discuss the difficult logistics, disease, and morale issues of deploying their troops to the region (Short, 2010). A nation in complete upheaval, Vietnam created the perfect storm of large population movements and ecological and environmental disturbances. These factors, paired with the breakdown of civil relief structure and crowding in camps of safety allowed for not only disease spread, but emergence and re-emergence of disease long since conquered in may other parts of the world (Smallman-Raynor & Cliff, 2004).

The NAMRUs and Army Laboratories made good headway into the field of tropical medicine prior to American troop’s arrival in Vietnam, but there were further challenges yet to be seen. Malaria was, once again, the scourge of US troops in the jungle environment. Malaria infections were the top reason for medical disability in the US forces during the conflict (Ockenhouse et al., 2005). Once again, the prevention precautions and enforcement of prophylaxis compliance was left in the hands of the line officers (Cirillo, 2008). To illustrate the result of this arrangement, one author estimates that only 30% of all deployed US troops complied and finished all malarial treatments (Newton et al., 1994). While the lack of troop compliance was a sizable issue on its own, the emergence of chloroquine resistant *Plasmodium falciparum* proved to be an equivalent threat (Cirillo, 2008). News of chloroquine resistance accelerated research and development of other anti-malarial drugs, and soon mefloquine and halofantrine were approved for use (Ockenhouse et al., 2005). Additional care was then taken in prevention of malaria including permethrin-impregnated uniforms and tents, use of personal insect repellents like N,N-diethyl-meta-toluamide (DEET), reduced troop activity during the dusk and dawn hours (peak hours of mosquito activity), mandatory use of head and bed nets, tent screens, destruction of breeding sites near camps, and perhaps most importantly, making malaria controls in troops a command responsibility (Cirillo, 2008). Due to the emergence of chloroquine-resistance, all suspected cases of malaria (nonspecific fever syndromes) required definitive testing by blood smears for speciation (Washington, Brown, Palys, Tyner, & Bowden, 2009). This procedure produced a need for more and better laboratory personnel and facilities in the field.

The cries of overwhelmed medics did not fall wholly on deaf ears. The Vietnam conflict allowed for allocation of the first US military incorporation of laboratories for microbiology study coupled to field medical units (Washington et al., 2009). These laboratories made several notable advances and improvements to tropical medicine including quantitative assessment of wound contamination, wound closure biology, improvements to mycobacterial classifications and tuberculosis (TB) research, and recommendations toward malaria control. Perhaps one of the most salient contributions to military medicine was the development of Cary-Blair media. Where traditional lab media was relatively not suited for jungle climates, this new media allowed for samples to be viably moved over long distances with minimal refrigeration. This type of media is still used but the US military to this day (Washington et al., 2009).

While one of the most problematic of the infectious diseases encountered during this conflict, malaria was not a lone agent. Insecticide-resistant fleas were found carrying plague in areas of the jungle (Short, 2010). Research laboratories studied the ecology of the disease, leading eventually to the identification of the etiologic agent (later renamed as *Yersinia pestis*) (Washington et al., 2009). Filarial infections were still common, and dermal schistosomiasis irritation was noted (despite no true diagnosed cases of schistosomiasis) (Crum et al., 2005). While chikungunya was a known threat in the area, it was not a significant cause of morbidity or mortality for US troops in Vietnam (Endy et al., 2005). Penicillin-resistant gonorrhea raged through US troops, likely contracted from local brothels (Drexler, 2010).

While the microbiology attachments to medical units were useful, there remained a gap in reaching ahead of major troop movements to assess threats in those areas. Thus in 1965, the US Army Special Forces – Walter Reed Army Institute of Field Epidemiological Survey Team (Airborne) was formed (Dorogi, 2009). While the novel use of special force troops to accomplish reconnaissance and act as medical sentries proved useful, the program was cancelled in 1968. Accomplishments of the group encompassed work on the ecology and control of vectors, isolation of several rickettsial and viral organisms, identification of scrub typhus outbreaks as a continuing issue, demonstrated subclinical levels of plague infection and recommended strongly prioritizing research efforts toward wound care and drug-resistant malarial stains (Dorogi, 2009). This unit's achievements in forward medical research further cemented the need for amplified medical and environmental intelligence for deployment settings.

Concerns of biowarfare continued throughout this era as the Cold War raged on. While infectious diseases played their role in US action in Vietnam, the war, on the whole, was remembered as a conveyor of far uglier stratagems and strife (agent orange, mental illnesses and post-traumatic stress disorder [PTSD]) as the US was ushered into a comparatively peaceful decade.

Desert Storm and conflicts of the late 20th century.

Desert Storm and the series of US military conflicts in the late 20th century benefitted from the advancement of medical prevention and treatment of tropical and infectious diseases. Military medical focus shifted more toward studies on gender, proper nutrition provision via field pack MRE (Meals Ready to Eat) rations, hydration and electrolyte studies, and improvements to chemical and biowarfare protective clothing (Pandolf et al., 2011).

Despite medical prowess, infectious diseases maintained a foothold in the US military during this period. Many of the issues stemmed directly from compliance issues among the troops. For example, in 1992, Marines returning from Somalia caused the larges outbreak of stateside malaria since Vietnam because they failed to complete appropriate medication regimens (Newton et al., 1994). Self-reported compliance with malarial chemoprophylaxis was reported at 56% during this era. Failure of general vector control and personal protection was implicated in the heavy morbidity tolls of Dengue during Operation Uphold Democracy in Haiti in 1994. Twenty-five percent (25%) of field hospitalizations within the first six weeks of troops on the ground resulted from fevers, however diagnosis of Dengue was difficult due to need for IgM confirmation. An estimated 7% of the hospitalizations were for confirmed cases of Dengue during the deployment (Trofa et al., 1997).

Although the drug had been developed only a decade prior, mefloquine-resistant malaria fast became a threat, and doxycycline and azithromycin were approved for prophylaxis and treatment (Ockenhouse et al., 2005). Diarrheal diseases continued to pose a major issue, with approximately 50% due to enterotoxogenic *Escherichia coli* (ETEC) and *Shigella* species alone (Cirillo, 2008). Leishmaniasis resurfaced as a notable threat, yielding 20 confirmed cases of cutaneous disease from *Leishmania major* and 12 from *Leishmania tropica* (Crum et al., 2005). While these diseases caused relatively small counts in the way of mortality, the morbidity and lost man-hours due to infection were significant to force health and performance abilities in the field. Therefore infectious diseases continued to pose a threat to the American military machine, even into the dawn of the 21st century.

Current Deployment Threats to Force Health Management

Since the early years of the 21st century, US forces have primarily operated in deployment areas of southwest Asia, namely Afghanistan, Iraq, and supporting bases in neighboring counties. For the most part, these deployment climates are arid deserts, prone to extreme temperatures and unique local flora, fauna, and cultural norms. Despite modern medical evolvement through all previous conflicts, the American warfighter remains susceptible to infectious diseases, ultimately yielding reduced force health. The fact that US troops during these contemporary conflicts spend more continuous time deployed to forward locations than any prior US combatants, the increased physical, mental and emotional stressors can be linked to this increased susceptibility to illness (Cirillo, 2008).

Diarrheal diseases continue to pose the ultimate menace to deployed US troops in the desert (Sanders, Putnam, Riddle, & Tribble, 2005). In one study, nearly 76% of surveyed troops reported at least one incident of diarrhea during their deployment and more than 50% had repeated incidents. Despite minimal impact on mortality, morbidity in the Sanders, Putnam, Riddle, and Tribble study (2005) showed an average of three days of decreased work capacity for each case of diarrhea. Most cases of diarrhea in the desert have been attributed as non-infectious and traveler's diarrheal cases (W. Venanzi, personal communication, 09 April 2014). Traveler's diarrhea results from 'westernized' gut exposure to various enteropathogens found in less developed countries and tends to be less morbid than other bacterial and viral diarrheas (Lim et al., 2005). Of all of the infectious diseases, diarrheal syndromes are one of the major players in force health degradation in deployment locations across the globe.

In hand with the diarrheal diseases, a major concern in deployed locations is always food and water security. In the desert deployment environment, because water is generally scarce, safe and potable water sources are often difficult to secure (J. Fike, personal communication, 24 April 2014). The lesser quantities of safe water also can play into hygiene issues, as soldiers may have to balance water availability with the option to bathe regularly. In less austere deployment locations, bottled water is often the best option, but compliance in using bottled water exclusively (no ice in beverages, use in teeth-brushing, etc.) is often low (P. Puchta, personal communication, 14 April 2014).

Similarly, securing safe food sources is a chief concern in any deployed location. This requires the capability to assess the host country and their cultural food preparation norms to know whether local cuisine or food sources can be used, or if soldiers will have to subside on MRE rations (J. Fike, personal communication, 24 April 2014). Food-borne outbreaks of disease can occur when non-secure food sources are used or when troop education and surveillance does not preclude them from dining at local vendors. For example, in personal communication with Dr. K. VanValkenburg, he relayed a story of inspecting the military dining facility and finding camel meat being served under guise as another meat (personal communication, 14 April 2014). Despite briefings to avoid local vendors and other unsecured food sources, compliance with MRE-only restrictions is difficult to maintain, especially after long periods of restriction to these rations. Gastronomically frustrated troops are known to seek illicit food sources after these mandated meal restrictions are placed. Thus, foodborne illnesses continue as one of the most problematic concerns in current deployments (D. Rogers, personal communication, 27 May 2014).

Malaria continues to pose a threat, even in the arid desert environment. Camps near rivers or deltas are at increased risk for the disease, as well as other mosquito-borne diseases (J. Fike, personal communication, 24 April 2014). Increasing *Plasmodium* species resistance to anti-malarial drugs and prophylactic agents makes the research of new drugs and possible vaccine options a high priority (Ockenhouse et al., 2005). Dr. P. Puchta described that despite having prophylactic medications and personal protection supply (DEET insect repellent, bed nets, permethrin-impregnated uniforms), ensuring troop compliance is still a significant problem in prevention of malaria and other vector-borne diseases (personal communication, 14 April 2014).

Cases of both visceral and cutaneous leishmaniasis have been common in the desert deployment locations (Crum et al., 2005). Per Dr. J. Fike, visceral leishmaniasis cases have increased in incidence in certain areas, causing concern for increased disease morbidity and mortality (personal communication, 24 April 2014). While medical treatments for both forms of the disease have progressed successfully over the past couple of decades, the major issue remains in human behaviors and vector control. Patient reporting of sand fly bites and symptoms of the disease are often delayed and the troops return home before proper diagnosis of cutaneous disease occurs (K. VanValkenburg, personal communication, 14 April, 2014).

Respiratory diseases are a common reason for deployed personnel seeking medical care. Nearly 60% of patients complaining of respiratory issues have some form of reactive airway diseases (W. Venanzi, personal communication, 09 April 2014). Per dialogue with Dr. K. VanValkenburg, a large number of these environmental respiratory conditions are related to particulate matter in the air produced by detonation of explosive ordinances and native populations burning wastes (personal communication, 14 April 2014). Dr. W. Venanzi adds that around 30% of the respiratory cases were simple viral illnesses that passed without need for intensive treatment, and that only about 10% of respiratory diseases he encountered in his time in the desert had radiographic or other flagrant suppurative findings (personal communication, 09 April 2014). Like in previous wars, crowded living conditions and common fomites among deployed troops contribute greatly to spread of infectious respiratory diseases (D. Rogers, personal communication, 27 May 2014).

While their magnitude of threat is less, several other conditions have been cited as significant force health issues in the current desert deployment environment. A 2009 study by Washington and colleagues revealed that native Afghani populations have increasing rates of TB and increasing troop contact with natives increases their exposure risk to the disease. Moreover, in the urban settings often encountered, troops have increased exposure to local animals, often feral or abandoned dogs. Despite command mandates for troops to not make ‘pets’ of these animals, many do and multiple exposures to rabies have occurred (P. Puchta, personal communication, 14 April 2014). The hot, arid climate conditions, paired with hard work and the aforementioned hygiene impediments can lead to common skin irritations and infection with bacterial and fungal agents (K. VanValkenburg, personal communication, 14 April 2014). While these infections are rarely life threatening, they can affect a troop's ability to work at full capability.

Altogether, the variety of diseases currently countering US force health management are not wholly unlike those identified earlier in this manuscript from Smallman-Raynor and Cliff's report (2004). Venereal diseases (now called sexually-transmitted diseases or STDs) are still problematic in both deployed and garrisoned troops, despite force health management attempts at prevention education. While many of the fevers historically seen in warfighters are vaccine-preventable or can be treated definitively with medications, malaria and other diseases still pose major problems. Constitutional and local diseases, especially those of the respiratory tract are common. Nervous diseases, though not usually infectious, are an ever-more recognized group of diseases resulting from combat exposures. Lastly, dysentery and diarrheal diseases continue to plague deployed populations, not inflicting the loss of life seen in past wars, but imposing a great burden of morbidity. As military force health management and the public health community look forward, all of these disease groups must be considered to optimally protect US military forces in future conflicts.

Lessons Learned and Innovations from US Military Medicine

While infectious disease mortality rates decreased significantly though the 'trauma age' of US warfare, Army hospital admissions for infectious disease have outnumbered those for combat injuries since WWII (Schmaljohn, Smith, & Friedlander, 2012). This increased proportionate morbidity would suggest that infectious disease is still an integral factor in force health management. To summarize down the six group older classification of diseases by

Smallman-Raynor and Cliff (2004), four major categories of war diseases are identified to have major impacts on US force health: a) Malaria and mosquito-borne diseases, b) Diarrheal diseases, c) Respiratory diseases, and d) Parasitic and other infectious diseases. The lessons learned from history and progress in management and prevention of these disease groups are summarized below.

Malaria and mosquito-borne diseases.

Malaria and similarly transmitted mosquito-borne diseases affected the US military significantly in every major conflict. Likewise, the contributions toward prevention and cures for malaria have been largely influenced by military research and development. From the basics of avoiding marshes and wetlands to initial treatments with quinine and the refutation of ‘typhomalarial fever’, to Colonel Gorgas’ four major pillars of prevention: the military has helped radically transform the prevention, control, and treatment of malaria (Ockenhouse et al., 2005). Antimalarial medications remain on the forefront of military medical study, especially in the years following discovery of drug-resistant strains and areas endemic to different *Plasmodium* species. Insect migrations and drug-resistance are now electronically tracked for regions around the world, and medication regimens have been honed and improved to best fit mission needs. While there exists no vaccine that can aid in malaria prevention, as noted in the personal communications of many military physicians, the key to malaria control now is mainly in compliance with preventative methods.

Other arthropod-borne diseases have been similarly affected by the vector control techniques described above. In addition, military contributions involve the current work toward creation of a dengue vaccine (Endy et al., 2005; Sebeny & Chretien, 2013). Work toward this goal is slow at present because scientists lack a good animal model for infection and vaccine use, as well as funding issues for vaccine development. Yellow fever research from the Commission in the late 1800's spearheaded by Major Walter Reed to the development of the vaccine in the 1930's has greatly decreased the morbidity and mortality from this once-dreaded disease.

Diarrheal diseases.

Diarrheal diseases have been arguably the scourges of all armies throughout history, but no military has bested these diseases better than the US. Camp sanitation practices and personal hygiene mandates throughout the years of military conflict have improved living conditions for troops and directly affected incidence of infectious diarrheal outbreaks. The field and bench research conducted on cholera treatment has not only decreased morbidity and mortality for US troops, but for people around the world suffering from this disease (Lim et al., 2005). The perfection of an oral electrolyte cocktail during the Vietnam era decreased deaths significantly (despite the small proportion in early studies who died from pulmonary edema as a result of said treatment). It is now estimated that military research and innovation for the treatment of cholera has decreased the case fatality rate from 20-30% to less than 1%(Lim et al., 2005). Further studies on oral rehydration have confirmed that this technique is useful in all infectious diarrheas.

Additionally, military medical contributions have improved treatment regimes for dysentery from *Salmonella*, *Shigella*, and *Campylobacter* species (Lim et al., 2005). These improvements include use of loperamide selectively as an anti-diarrheal agent and azithromycin treatment for fluoroquinolone-resistant *Campylobacter*. General improvements for traveler's diarrhea management involve application of pressurized anhydrous chlorine to drinking water, fluid filtration systems, and chlorination of cloth water bags (known as Lyster bags, after their creator). Current military research is focused on developing effective vaccines for Shigella, Campylobacter, and ETEC, and research and development continue on oral rehydration techniques (Lim et al., 2005). The goal is not only to prevent these diarrheal diseases but to decrease time of illness that troops spend so that they may be returned quickly to post.

Respiratory diseases.

Prevention of deadly respiratory diseases became a hallmark achievement aided by military medical researchers in the early 20th century. Vaccine development and improvement has been an integral part of force health protection and the benefits have extended throughout the world (Hoyt, 2006). This success has been largely in part to the depth and breadth of field research and patient data available to military scientists and physicians and the use of military outbreak surveillance data for civilian extrapolation (Sebeny & Chretien, 2013). Respiratory diseases continue to pose a threat to US troops, both deployed and in garrison. While vaccine developments are often seen as the highlight of military contributions toward respiratory disease defeat, the improvements in camp sanitation and regulations regarding infirmed troops also fostered advances toward prevention of outbreak spread. These improvements have significantly reduced the morbidity and mortality from these diseases in the past two centuries.

Parasitic and other infectious diseases.

Dependent on the locations to which US military personnel have deployed, they have encountered a variety of pathogens along the way. As new agents of disease were encountered and lessons were learned, military scientists and public health officers worked furiously to create both better prevention and treatments for these diseases. Instilling mandatory vaccination against typhoid fever in WWI gave the US troops the needed edge to fight in the trenches (Mostofi, 1968). Vector reduction, not only of mosquitos as previously described, but also of fleas, body lice, ticks, and flies, has served as paramount primary preventative measures toward infectious disease control in deployed troops (Crum et al., 2005; Mostofi, 1968; Short, 2010).

Additionally, discoveries regarding hemorrhagic fever and renal syndrome (HFRS) led to endeavors to minimize soldier contact with rodents and their excreta (Endy et al., 2005). Further reduction of HFRS-associated mortality has resulted from military pioneering in use of ribavirin treatment.

Perhaps some of the most distinguishing studies conducted by military health researchers in recent years have been on the control and treatment of leishmaniasis. Prevention of sand fly bites via vector control methods factors largely in primary prevention of the disease. DEET formulations have been developed than offer up to twelve hours of protection, and the military has increased issuance of permethrin-impregnated uniforms. Discovery of additional methods of spread has also been important. US military researchers discovered that leishmaniasis could persist in blood units held under blood bank storage conditions for donation for up to 15 days, allowing possible transmission of both *L. tropica* and *L. donovani* (Crum et al., 2005). Now blood units given for donation are screened to prevent this method of disease transmission.

Along with preventing disease spread, US military research has enhanced the treatment of leishmaniasis. Pentostam, a primary antimonial drug for treatment of cutaneous leishmaniasis has a known terrible side effect profile: 97-98% of patients develop chemical pancreatitis, 67% elevated liver function tests, 58% myalgias and arthralgias, and 54% electrocardiogram changes. Military research has focused in on different regimens to lessen or prevent these effects altogether (Crum et al., 2005). For example, decreasing dosage to a shorter course (ten days) has been noted to be equally effective as longer courses of treatment. High cure rates (up to 97%) have been found using the drug, AmBisome, for treatment of visceral leishmaniasis (Crum et al., 2005). Perhaps the most vital of breakthroughs the US military has made in leishmaniasis prevention is development of computer and satellite-based mapping systems that track the seasonal migrations of sandflies and rodent reservoirs for the disease. Further development of similar systems for other vectors and infectious diseases will be vital for infectious disease prevention in the future of US military conflict.

Recommended Transitions for Force Health Management in Cross-global Flux

Remembering the lessons learned from previous experience and integrating the current recommendations for infectious disease control and prevention will be key in force health management in the event of a cross-global flux toward more tropical deployment sites. This transition will require cooperation and collaboration between the branches of the US military as well as with organizations from industry and academia. The broad health protection suggestions currently provided to any global traveler apply also to all deploying personnel, and should be heeded and added to as mission requirements might dictate.

Malaria prevention for travelers consists chiefly of bite prevention and compliance with prescription antimalarial prophylaxis (CDC, 2014a). Bite prevention is suggested by barrier (long sleeves, netting), chemical (DEET, other insect repellants), and avoidance methods. These methods are identical to those for prevention of bites for other vector-borne diseases (CDC, 2014b). While for some diseases like yellow fever, a vaccine is available, others like dengue are prevented solely by avoidance of vector exposure (CDC, 2014b; CDC, 2014c).

Prevention of diarrheal diseases is one of the cornerstone objectives of travel and tropical medicine. While a few of the diarrheal diseases are vaccine-preventable (e.g. hepatitis A), the most common preventative techniques for diarrheal diseases is careful selection of food and water sources (CDC, 2014d). Food and water safety are not sufficient to completely prevent diarrheal diseases though, so good judgment should be executed in accommodation sanitation, exposures to indigenous animals (including humans), and individual hygiene practice of the travelers themselves (CDC, 2014e) In some cases of infectious diarrhea, such as those from ETEC and *Shigella*, antibiotics can be the appropriate choice (CDC, 2014f ; CDC, 2014g).

Respiratory diseases are an increasing concern in travel medicine, especially given the recent outbreaks of pandemic influenzas strains SARS (Severe Acute Respiratory Syndrome), and most recently MERS (Middle East Respiratory Syndrome) (Hilgenfeld & Peiris, 2013). Many respiratory diseases suffered in past military conflicts are vaccine-preventable, including measles and influenza (CDC, 2014h). Thus vaccination is paramount in all traveling or deploying personnel. Avoidance of sick-contacts and proper hygiene comprise the other major recommendations for prevention of respiratory diseases, both for vaccine-preventable ones like influenza and non-vaccine preventable diseases such as TB (CDC, 2014i; CDC, 2014j).

Dependent on the location of travel, travelers should be aware of other parasitic and other infectious disease threats. Travelers who are at increased risk for local animal contact should be educated about rabies and how to avoid animal bites, and may possibly be advised to get the rabies vaccine series prior to travel if their risk of exposure is high enough (CDC, 2014k). Parasitic diseases like schistosomiasis can be contracted through contact with contaminated fresh water (often through wading, swimming or bathing), so travelers visiting areas where the disease is endemic should be prepared to adjust to these risks (CDC, 2014l).

Given these current recommendations from CDC and the medical and public health communities, the US military will have a strong base for force health preparation in the event of cross-global flux toward more tropical climates. The Department of Defense relies heavily on these networks as well as the National Center for Medical Intelligence, other command structures, and civilian consultants from organizations for pre-deployment medical intelligence (J. Fike, personal communication, 24 April 2014). The network for large-scale deployment planning is dense and strong, so major paradigm shifts to this portion of force health protection and management will not play a sizeable role during a flux from desert to tropics. Management of smaller deployment units, however, could be a more difficult option, as often these groups' pre-travel planning is left in the hands of local public health entities who not always prepared for this task.

Therefore, while a paradigm shift on large-scale force health management system will not be necessary in the case of a cross-global flux, the focus of the transformation of force health management will occur on a more subordinate level. The primary execution themes for these modifications should be focused on force management education, environmental and disease-specific concerns, and, to a limited degree, biowarfare.

Force Management Education

The primary paradigm shift in the case of a cross-global flux of US troops will need to be in education of all levels associated with force health management, from command to the lowest ranking troop to civilian contractors (D. Rogers, personal communication, 27 May 2014). Prior to any military deployment, public health and medical personnel create and deliver location and mission-specific briefings to commanders and troops detailing the common health threats in the deployment region. An ability to read and comprehend health recommendations regarding vaccines is strongly correlated to good medical decision-making in patients planning to travel abroad (vanHerck, Zuckerman, Castelli, Damme, & Walker, 2003). Military personnel have relatively high average health literacy rates in comparison to the US civilian population (Weld, Padden, Ricciardi, & Bibb, 2009). This high health literacy paired with robust briefing from DoD sources builds a solid education base for deploying military personnel. However, many civilian contractor organizations provide a less vigorous pre-deployment preparation in health risks, often resulting in increased knowledge and compliance (P. Puchta, personal communication, 14 April 2014). Given that the prevention of many infectious diseases are heavily compliance-based (be it for medication usage, vaccines, or environmental factors), all involved parties need to understand the regulations and reasoning behind them.

In addition, as noted by Dr. J. Fike, education of the public health community and their partners will be paramount as well (personal communication, 24 April 2014). As large-scale deployments of troops are generally decreasing in frequency, the concern is for those small groups deploying – ones that, as mentioned earlier, may not receive the benefit of full federal research and briefing for their health protection. Local public health offices must have individuals trained and qualified to determine disease threats for a region, and in using all resources available to them, create risk mitigation strategies custom-tailored to a small group deploying to an austere environment.

Education will not apply only to the deploying troop, but also to the surrounding community. Since their inception in the late 1930s, medical science has increasingly relied upon and overused antibiotics for disease management as opposed to primary prevention with vaccines (Hoyt, 2006). Antibiotic resistance continues to present a growing problem worldwide and specifically in US military recruits (Meyer et al., 2011). Macrolide antibiotics (e.g. azithromycin, better known as the Z-pak) are often used for disease prophylaxis and disease treatments in patients allergic to penicillin; however increasing recruit resistance is posing a threat to their continued use. Antibiotic resistance has been traditionally viewed as a developed country problem, but the growing antibiotic resistance in developing counties (particularly in tropical regions) could overshadow the US troops' antibiotic resistance issues as a major health threat. As early as the Vietnam War, penicillin-resistant gonorrhea strains were seen in US troops, likely due to the prophylactic dosing of girls in the local brothers by well-meaning medical personnel (Drexler, 2010). In Southeast Asia, the antibiotic resistances of enteric pathogens like *Shigella*, ETEC, *Salmonella*, and *Campylobacter* has increased dramatically in recent years (Meyer et al., 2011). Some Shigella species have even acquired quadruple antibiotic resistance (tetracycline, sulfonamide, streptomycin, and chloramphenicol resistance), theorized to have developed from genetic material shared from E. coli strains (Drexler, 2010). Healthcare-associated pathogens with increasing antibiotic resistance are also on the rise in developing nations, likely due to import on military forces throughout the course of time (Meyer et al., 2011). Thus, it is important for education to continue, not only for physicians, but also for the public on the dangers of antibiotic over-prescription and resistance.

Vaccination is a hotly debated and discussed topic, and Americans on the whole are known to be often resistant to or non-compliant with vaccine recommendations (Polak et al., 2011). Concerns about vaccine safety, seen almost as frequently now as a nightly newscast, spawned the creation of the Global Advisory Committee on Vaccine Safety. This committee was founded by the World Health Organization for the continued research and study into this field (Global Advisory Committee on Vaccine Safety, 2013). Many military members have cited the anthrax vaccine as a generally untrusted vaccine(Polak et al., 2011). The Polak study (2011) showed that only 40.6% of surveyed deploying Army personnel to Iraq and Afghanistan had appropriately completed the anthrax vaccine series. Another study found that 60% of troops surveyed did not believe that the anthrax vaccine was safe (Polak et al., 2011). Concerns about vaccine safety are a major hurdle to ensuring maximal personnel vaccination levels and resulting force health protection.

Failure to recognize risks associated with travel also leads to less compliance with vaccination (Lopez-Velez & Bayas, 2005). Military members are not immune to this common argument toward not vaccinating. Despite thorough briefings on importance and the compulsory nature of vaccination in the US armed forces, an estimated 36% of current members are missing at least two required vaccines (Polak et al., 2011). This study also showed that, similar to civilian counterparts, compliance with vaccination was positively correlated with belief in physician advice. Thus, military physicians or those treating deploying troops must be well versed in information regarding the vaccines they recommend. Vaccine recommendation from the command level results in both positive and negative beliefs toward vaccine necessity among troops. Regardless, per Dr. J. Fike, line leadership needs to be better involved in the medical risk assessment and planning process so that they can better prioritize recommendations and ensure compliance among their troops (personal communication, 24 April 2014).

Physician education on the diseases encountered by military troops in deployed locations is often less than optimal. As previously noted, tropical medicine had barely surfaced in US medical education 60 years ago, and despite impressive progression since that time, it is still a evolving field (Mostofi, 1968). Many physicians deployed with military forces do not have strong background in infectious disease, and thus are often ill equipped or unsuspecting of infections they might encounter. As in any pre-travel consult, in preparation for deployment, physicians need to work with public health personnel to assess and recommend appropriate force health protection measures (Rossi & Genton, 2012). Medical staff preparation for deployment continues to require improvements and this will be imperative in the event of cross-global flux.

Partnerships will be key in improving force health management and protection. All to often, the branches of the US military fail to cooperate with one another, and conflicting emphases and regulations are repeatedly problematic (K. VanValkenburg, personal communication, 14 April 2014). The Department of Defense has made several mandates toward inter-force cooperation, but there is still considerable ground to be gained in this regard. Partnerships within the military are vital, but outside partnerships are of equal importance. While many of the medical industry and academic foci tend toward other horizons, vaccine development is still arguably the most important medical factor in force health protection (Schmaljohn et al., 2012). Unfortunately, the cost of vaccine development is high, the process time consuming, and the returns often incremental. Without partnership with industry and academia, the current level of military vaccine research and development is unsustainable.

Despite the shortcomings in military partnerships to date, the past has shown that collaboration toward the greater good of force health protection and national safety is possible (Hoyt, 2006). As noted by Alfred N. Richards, chair of the Committee on Medical Research:

> [the] unselfish zeal, cooperative spirit, and the competence with which our civilian investigators, laying aside more agreeable pursuits, entered into the attack on problems whose solution was vital to our fighting forces… Never before, we believe, has there been so great a coordination of medical scientific labor. (Quoted in Hoyt, 2006, p. 41)

The US military is not devoid of collaborators today. For example, the Shoreland, Inc. electronic publication, *Travax (*www.travax.com*)*, is one of the primary sources used by the DoD for travel preparation information (J. Fike, personal communication, 24 April 2014). Partnerships such as these are important for the US military to build, foster, and maintain in order to best manage force health protection in the future.

Environmental and Disease-Specific Concerns

Clearly, a change in physical deployment location and climate will pose transformation needs in force health protection measures. Despite the blatant differences in the climates and subsequent exposures, the process for risk assessment and mitigation planning will be essentially the same. Large-scale troop deployments arise with a thorough and complex consultation and planning phase. The recommendations of the CDC, National Center for Medical Intelligence, and other entities will generally suffice for expected disease and environmental health threats. The small-volume deployments that receive less formal support and direction will be of chief concern in this transition, as well as the public health and medical communities who will advise them.

While heat-related disease is common in the desert employment environment, considerations for a more tropical environment will need to focus on increased humidity. Increased moisture levels will affect food safety, hygiene issues (e.g. fungal and bacterial infections), and, perhaps most importantly, the propensity for mosquito breeding. Water sources may be more largely available but will not necessarily be more potable than those found in the desert. Hydration and electrolyte replacement will continue to be of vital importance (Pandolf et al., 2011; Pollard & Rice, 2008). The tropical climate also boasts a more robust plant and animal assortment, thus exposures to them should be a focus of planning a mission to a specific tropical location (J. Fike, personal communication, 24 April 2014). Much of this information can also be obtained by communication with the local US embassy in or near the deployment location, if one is present (P. Puchta, personal communication, 14 April 2014).

Current recommendations for control of malaria and mosquito-borne diseases, diarrheal diseases, respiratory diseases, and parasitic disease have been discussed previously in this section.

Specific tropical and infectious diseases like schistosomiasis, leptospirosis, brucellosis, rabies, typhoid, tick-borne diseases like Lyme disease, should be included in preparation for deployment in endemic regions. Considerations toward antibiotic resistance patterns in the deployment should also be taken into account when planning for deployments in certain locations.

The concern for emergence or reemergence of diseases should always be accounted for in deployment planning. Many current influenza-like illnesses and other zoonotic diseases originate from Southeast Asia and Pacific regions. A resulting pandemic threat could emerge quickly in a deployment situation to this area. For some influenza strains, such as H5N1, the WHO has only limited supply of effective vaccine, so both prevention and treatment options would need to be developed quickly in the case of outbreaks (Heymann, 2008). Coronaviruses, like those causing SARS and MERS, can result from animal sources, laboratory accidents, or the possibility of undetected circles of transmission among humans that the scientific community has yet to recognize (CDC, 2014m). The chance of more malevolent emergence or reemergence of infectious diseases also continues to threaten force health management, namely via biowarfare.

Biowarfare and Bioterrorism

It would be negligent to complete a historical and current review of military infectious disease threats and project toward future needs without at least briefly touching on biowarfare and bioterrorism. Biological warfare has been used for centuries, spreading plague, smallpox, and host of other infectious diseases. Winston Churchill commented that:

> [P]estilences methodically prepared and deliberately launched… Blight to destroy crops, anthrax to slay horses and cattle, plague to poison not armies but whole districts – such are the lines along which military science is remorselessly advancing. (Quoted in Drexler, 2010, p. 244)

Despite the “Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases and of Bacteriological Methods of Warfare” (commonly called the Geneva protocol of 1925) being signed into law that same year, biowarfare preparations and use have continued worldwide, with US involvement notwithstanding (Riedel, 2004). In 1951, William Creasy, the leader of the Army Chemical Corps germ weapons program alleged “Biological warfare is essentially public health and preventative medicine in reverse” (Drexler, 2010, p. 246). This was the methodology that the US, Soviet Union, and many other countries employed in their bioweapons programs well into the later 20th century.

While biowarfare tactics are clearly prohibited by international law and highly unethical, US military command and homeland defense would be imprudent to presume that biowarfare threats no longer exist. While primary prevention via a global eradication of all biowarfare agent manufacture would be ideal, development of secondary and tertiary prevention should be focused upon for early detection and effective treatment and outbreak mitigation can occur (Riedel, 2004). Both the DoD and medical industry assets should prioritize continued research and development toward countering bioterrorism and biowarfare, especially in the possibility of cross-global flux and military engagement with novel adversaries.

Conclusions and Study Limitations

In conclusion, American military history is rich in successes of innovation and lessons learned through failure in the prevention, control, and treatment of tropical and infectious diseases. Current deployments in desert environments have provided continued research and development toward infectious disease study, despite a relative decrease in civilian medical attentiveness toward the field. In the case of a cross-global flux of US troop deployment resulting in in distribution to more tropical locations, the military will need to transition current deployment planning strategies in order to prepare. While the large-scale deployment force health protection and planning structure is secure, changes will need to be executed in force health management education, environmental and diseases-specific concerns, and biowarfare awareness. The themes for this transition are summarized in Table 4. Execution of this transition will allow more efficient and efficacious force health management and protection for American warfighters across the globe.

Table 4. *Summary of Force Health Management Transition Points in Preparation for Cross-global Flux into More Tropical Deployment Environments*

Force Management Education	
	Continued improvements of pre-deployment briefing
	Better pre-deployment education of civilians/contractors
	Education of stateside civilian public health offices to facilitate pre-deployment education and health needs
	Continued healthcare and public education on antibiotic resistance
	Education on vaccine safety and efficacy
	Continued improvement of military vaccination programs and tracking
	Physician education on tropical diseases
	Partnerships between US military branches
	Partnerships with academia and medical industry
Environmental and Disease-specific Concerns	
	Continued planning partnerships with military and civilian components
	Increased climate focus on humidity and moisture threats
	Create specific awareness to flora and fauna in tropical locations
	Partnering with local embassies (when available)
	Region-specific infectious disease prevention strategies - for every deployment, every location, every time
	Enact plans for emerging or reemerging epidemics
Biowarfare and Bioterrorism	
	Foster awareness of risks and education on signs and symptoms
	Continue education in prevention and countering of attacks

This study was limited by several factors. The design of the study itself is limiting, as no raw data was collected, but rather literature and anecdotal review were used to create a portrait of history and current US military conflict. The literature review and personal communications for this manuscript were limited to unclassified materials, which while useful for this general overview, cannot completely describe historical or current military threats posed by infectious diseases. The small number of contributing physicians and their limited experiences may or may not paint a full picture of challenges faced in current deployment environments. Nonetheless these recommendations are offered as a starting point for force health management and protection in transition toward new warfronts in the 21st century.

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Appendices

Appendix A: Military Physician Contributors

Jim Fike, MD
Col, USAF (ret), MC

Paul Puchta, MD
LtCol, USAF, MC, FS

Mark Summers, MD
LtCol, USAF (ret), MC, FS

David M Rogers, MD, MPH
Col, USAF, MC, SFS

Kevin VanValkenburg, DO
Lt Col, USAF, MC, FS

William E. Venanzi, MD, FACP
Col, USAF (ret), MC

Appendix B: Infectious Disease and the Warfront Questionnaire

PH, ID, and the Evolving Warfront

- How much time have you spent time in the desert deployment environment?
  - What were the major public/force health concerns in the desert?
  - What were the major disease (particularly infectious) concerns in the desert?
- Have you deployed to or spent a considerable amount of time in another climate environment (tropical, subtropical, forests, etc.)?
  - What type of climate did you encounter?
  - What were the major public/force health concerns in that climate?
  - What were the major disease (particularly infectious) concerns in that climate?

- In past deployments/travels what have been some of the most glaring mistakes made by the military/agency traveled with in regards to disease prevention?
- What lessons have the military/other agencies learned about disease prevention and force health management in different climates?

- In the case of a force transition from the desert to a more tropical environment (eg. Southeast Asia), what paradigm shifts would need to occur in force health protection?
  - What changes in infectious disease threats?
  - Will there be changes in possible bioterrorism threats?
  - What changes in other PH/force health protection?

- Do you have any tropical or infectious disease background? (Please list along with basic signature-line demographics for quoting purposes.)

Appendix C: IRB Approval

WRIGHT STATE UNIVERSITY

Office of Research and Sponsored Programs
201J University Hall
3640 Col. Glenn Hwy.
Dayton, OH 45435-0001
(937) 775-2425
(937) 775-3781 (FAX)
e-mail: rsp@wright.edu

DATE: May 02, 2014

TO: Joanna M. Nelms, M.D., MPH Candidate
Community Health
James Ebert, M.D., Faculty Advisor

FROM: B. Laurel Elder, Ph.D.
Chair, IRB-WSU

SUBJECT: SC# 5525
'Lessons Learned and Future Projections for Force Health Protection and Infectious Disease in Military Deployment Settings'

Your study does not meet the definitions for human subjects research. Therefore the proposal submitted does not need approval from the Wright State University Institutional Review Board.

If you have any questions or require additional information, please call Jodi Blacklidge, Program Facilitator at 775-3974.

Thank you!

Appendix D: List of Competencies Used in CE

List of Tier 1 Core Public Health Competencies

Domain #1: Analytic/Assessment
Identify the health status of populations and their related determinants of health and illness (e.g., factors contributing to health promotion and disease prevention, the quality, availability and use of health services)
Describe the characteristics of a population-based health problem (e.g., equity, social determinants, environment)
Use variables that measure public health conditions
Identify sources of public health data and information
Recognize the integrity and comparability of data
Identify gaps in data sources
Adhere to ethical principles in the collection, maintenance, use, and dissemination of data and information
Describe the public health applications of quantitative and qualitative data
Use information technology to collect, store, and retrieve data
Describe how data are used to address scientific, political, ethical, and social public health issues
Domain #2: Policy Development and Program Planning
Identify mechanisms to monitor and evaluate programs for their effectiveness and quality
Apply strategies for continuous quality improvement
Domain #3: Communication
Identify the health literacy of populations served
Communicate in writing and orally, in person, and through electronic means, with linguistic and cultural proficiency
Solicit community-based input from individuals and organizations
Participate in the development of demographic, statistical, programmatic and scientific presentations
Domain #4: Cultural Competency
Recognize the role of cultural, social, and behavioral factors in the accessibility, availability, acceptability and delivery of public health services
Domain #5: Community Dimensions of Practice
Collaborate with community partners to promote the health of the population
Describe the role of governmental and non-governmental organizations in the delivery of community health services
Identify community assets and resources
Domain #6:Public Health Sciences
Describe the scientific foundation of the field of public health
Identify prominent events in the history of the public health profession
Identify the basic public health sciences (including, but not limited to biostatistics, epidemiology, environmental health sciences, health services administration, and social and behavioral health sciences)
Describe the scientific evidence related to a public health issue, concern, or, intervention
Retrieve scientific evidence from a variety of text and electronic sources
Discuss the limitations of research findings (e.g., limitations of data sources, importance of observations and interrelationships)
Partner with other public health professionals in building the scientific base of public health
Domain #7: Financial Planning and Management
Describe the organizational structures, functions, and authorities of local, state, and federal public health agencies
Adhere to the organization's policies and procedures
Report program performance
Translate evaluation report information into program performance improvement action steps
Apply basic human relations skills to internal collaborations, motivation of colleagues, and resolution of conflicts
Demonstrate public health informatics skills to improve program and business operations (e.g., performance management and improvement)

Domain #8: Leadership and Systems Thinking
Incorporate ethical standards of practice as the basis of all interactions with organizations, communities, and individuals
Describe how public health operates within a larger system
Participate with stakeholders in identifying key public health values and a shared public health vision as guiding principles for community action
Identify internal and external problems that may affect the delivery of Essential Public Health Services
Use individual, team and organizational learning opportunities for personal and professional development
Participate in mentoring and peer review or coaching opportunities
Participate in the measuring, reporting and continuous improvement of organizational performance
Describe the impact of changes in the public health system, and larger social, political, economic environment on organizational practices

List of Concentration Competencies Used in CE:

Public Health Management:
Have a knowledge of strategy and management principles related to public health and health care settings
Be capable of applying communication and group dynamic strategies to individual and group interaction
Know effective communication strategies used by health service organizations
Have an understanding of organizational theory and how it can be utilized to enhance organizational effectiveness
Have a knowledge of leadership principles
Know change management principles
Have a knowledge of successful program implementation principles
Have a knowledge of strategies used for monitoring, evaluating, and continuously improving program performance
Be capable of applying decision-making processes
Have a knowledge of systems thinking principles
Have a knowledge of human resource principles to enhance organizational management, motivate personnel and resolve conflict
Know strategies for promoting teamwork for enhanced efficiency
Have an understanding of effective mentoring methods
Be able to assess and resolve internal and external organizational conflicts
Be able to determine how public health challenges can be addressed by applying strategic principles and management-based solutions
An awareness of ethical standards related to management
A knowledge of ethical standards for program development