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# 2014: A Record-Breaking Year for West Nile Virus Positive Mosquito Pools in Harris County and the City of Houston, Texas

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ABSTRACT

In the 14 years since the emergence of West Nile virus (WNV) in Harris County and the city of Houston, Texas, the number of mosquitoes infected with the virus has fluctuated with several high and low count years. During this 14-year period, mosquito surveillance operational areas in Harris County were expanded from 248 to 268 and the distribution of the virus activity in mosquitoes varied from year to year. Operational areas with WNV infected mosquitoes increased from 137 in 2002 to 197 in 2006, decreased to 71 areas in 2007, and to an all-time low of 18 in 2008. The number increased to 78 areas in 2009, 96 in 2010, 133 in 2011, and 177 in 2012, but fell to 73 in 2013. However, 234 areas were confirmed in 2014, and only 138 in 2015. The WNV transmission was high in 2002 with 227 WNV positive mosquito pools. The number of positive mosquitoes remained elevated for a number of years and then declined from 2007 to 2010. Three record high years for WNV activity were: 2005, 2006, and 2011 with 698, 838, and 605 confirmed positive mosquito pools, respectively. Viral activity declined in 2012, followed by a marked decline in 2013 with only 147 WNV positive mosquito pools. In 2014, a record-breaking number of 1,286 WNV positive mosquito pools were confirmed in Harris County and the city of Houston, the most ever in a single season, while 406 were confirmed in 2015.

West Nile virus (WNV) is a mosquito-transmitted, arthropod-borne virus maintained in nature in a bird-mosquito transmission cycle. It belongs to the genus *Flavivirus* (family Flaviviridae) and is closely related to St Louis encephalitis (SLE) virus. Humans, horses, and other vertebrates are dead-end hosts that do not produce significant viremia and thus do not contribute to the transmission cycle.[1] Prior to 1999, WNV was geographically distributed in Africa, the Middle East, India, and western and central Asia, with occasional epidemics occurring in Europe.[2] During the summer of 1999, WNV was detected in New York and has since emerged in all 48 contiguous states of the United States (not in Alaska and Hawaii) and other areas of the Americas including Canada, Mexico, and the Caribbean Islands.[3,4] It was introduced into Harris County (HC), including the city of Houston, Texas, during the summer of 2002 with virus outbreaks occurring each year thereafter.[5] The primary vector of WNV in HC is the *Culex quinquefasciatus* Say mosquito.

The emergence of WNV into HC and the Houston metropolitan area in 2002 brought about major changes in mosquito surveillance and testing for arboviruses at Harris County Public Health, Mosquito Control Division (MCD). Prior to that, the main focus for surveillance, testing, and control was SLE virus which then shifted to WNV. Between 2002 and 2005, mosquito monitoring and trapping were expanded from 248 to 268 operational areas within HC and Houston (Figure 1).

The enzyme-linked immunosorbent assay (ELISA) antigen capture assay, originally developed for SLE, was adapted for WNV.[6] Subsequently, the number of specimens being tested increased dramatically. The Rapid Analyte Measurement Platform (RAMP) test (Response Biomedical Corp, Burnaby, British Columbia, Canada), a rapid and accurate WNV antigen assay, was successfully incorporated into the testing program in 2003.[7]

Because the MCD vector control decisions were based upon mosquito surveillance and virology laboratory test data, the time between submitting mosquito samples for testing and receiving test results initially posed a significant limitation. Mosquito pool samples were tested in weekly batches and the lag time from collection to obtaining test results was usually a week or longer. Changes in the surveillance and virology laboratory testing schedules and timelines were implemented in 2005-2006. Specimen processing, ELISA, and RAMP testing

*The *US Army Medical Department* (AMEDD) *Journal* thanks Dr Debboun for his work developing this issue focused on public health. He coordinated and managed the call for manuscripts, then the review and selection of the content, as he has done annually developing similar issues since 2006. When he retired as a Colonel from the US Army, he was Director of the Department of Preventive Health Services at the AMEDD Center and School and Chairman of the Editorial Review Board of the *AMEDD Journal* at Fort Sam Houston, San Antonio, Texas.

Figure 1. Mosquito surveillance map showing 268 mosquito control operational areas in Harris County, which includes the city of Houston, Texas.

were then conducted 3 times per week. Consequently, the gaps between collection, testing, and reporting of results were narrowed to 3 days, which also expedited control efforts.

Detailed mosquito surveillance and testing records were recorded in a Microsoft Access database maintained by the Technical Operations Branch of the MCD. At the end of each year, the data was analyzed and reported in the Annual Summary Reports of Mosquito Surveillance and Virology Laboratory Test Results for the years 2002-2015.

## Materials and Methods

In pretest preparations in the virology laboratory at MCD, pooled samples of *Cx quinquefasciatus* mosquitoes were placed in microcentrifuge tubes with a bovine albumin buffered solution (BA-1) and one steel bead per tube. The specimens were ground in Qiagen TissueLyser II mills (Qiagen Sciences, Inc, Germantown, MD), and clarified by centrifugation. The mosquito homogenates were screened by ELISA Antigen Capture Assay for both SLE and WNV.[6] An ELISA plate reader (BioTek EL800), in conjunction with BioTek KCJunior software (BioTek Instruments, Inc, Winooski, VT) were used to measure the degree of color development and light absorption within the individual test plate wells. The reader/software system determined the amount of antigen in each sample and calculated the mean optical density (OD) value of each set of duplicate test wells. Positive ELISA tests were determined by comparing the samples' OD values to the mean OD of the negative controls.The resulting data was exported to a Microsoft Excel spreadsheet to tabulate the comparative values. The WNV ELISA positive pools were further tested by the RAMP test (ADAPCO, Sanford, FL) for confirmation.

The RAMP WNV assay is an immunochromatographic test for detection of WNV in mosquitoes. A measured amount of the test samples in RAMP buffer was transferred to the sample well of the WNV test cartridge (TC) using a pipette and the supplied assay pipette tip. The TC uses latex particles that are fluorescently labeled and tagged with WNV antibodies. As the sample migrated through the cartridges, WNV antigen bound particles

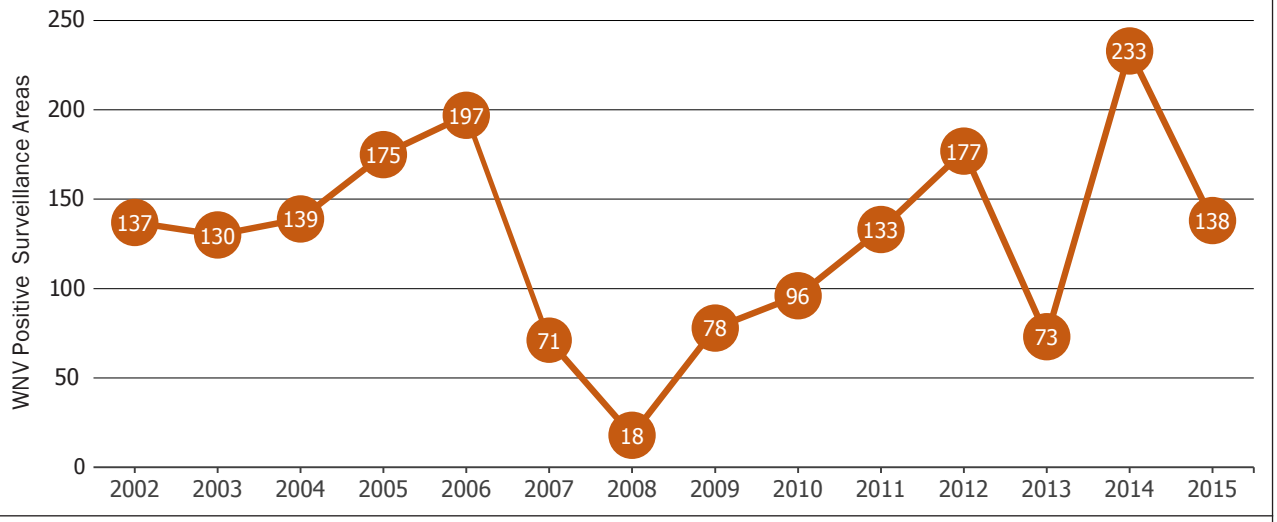


Figure 2. Number of surveillance areas with confirmed WNV positive *Culex quinquefasciatus* mosquito pools identified in Harris County, including the city of Houston, Texas, each year from 2002 to 2015.

were immobilized at the detection zone by specific antibodies and a portion of excess (control) particles were immobilized at the internal control zone.[8]

The RAMP reader measured the amount of fluorescence emitted by the particles bound at each zone and calculated a ratio between the measurements.[7] The results were displayed as a numerical value (RAMP units) on the reader screen. From 2003 to 2013, mosquito pools with RAMP units greater than or equal to 2.4 were confirmed as WNV positive. This low value was determined to be acceptable after discussions with the manufacturer showed that the BA1 grinding buffer used in the MCD virology laboratory affected the reading curve of the RAMP system. In 2014, the negative cut-off value was changed after the lowest numerical value displayed for the RAMP WNV test was revised by the manufacturer to 10.0 units (from 2.4). Results below 10.0 display as 10 units or less and are considered negative. These updated values were used in both 2014 and 2015 for confirmation of WNV ELISA positive pools.

## Results

The distribution of virus activity in mosquitoes in the 268 surveillance areas varied similarly to the number of positive mosquitoes. As shown in Figure 2, over the last 14 years, the number of areas with confirmed WNV positive mosquitoes varied from year to year. There were 137 infected areas in 2002 and about the same number of areas in 2003 and 2004. The number increased to 175 in 2005 and to 197 in 2006. There was a drastic decrease to 71 areas in 2007 and an all-time low of 18 in 2008. The number of positive areas rose to 78 in 2009, 96 in 2010, and 133 in 2011. The number spiked to 177 in 2012, then drastically dropped to 73 areas in 2013. In 2014, an unprecedented 234 WNV positive areas were confirmed, while only 138 in 2015.

Records in the mosquito surveillance database show that the inner Highway 610 Loop areas, Kingwood in northeast HC, and the northwest quadrant of HC provided hot spots of viral activity during the majority of the peak mosquito seasons. From 2009 to 2013, heavy concentrations of WNV were also found in the southeast, southwest, north-central, and far west areas.

Due to the widespread presence of WNV, the number of *Cx quinquefasaciatus* and other mosquito species (*Aedes albopictus* Skuse and *Ae aegypti* (L.)) tested more than doubled after 2002. In 2002, 7,298 mosquito pools were tested, and more than 11,000 were tested annually beginning in 2003 (Figure 3). The numbers progressively increased, reaching a record of approximately 16,750 mosquito pools screened for WNV and SLE in both 2008 and 2009. In 2010, there was a decrease in the number of mosquito pools tested (13,860), but an increase in 2011 (14,396) due to increased viral activity.

In 2012 and 2013, fewer than 15,000 samples were tested each year. Surveillance and testing continued throughout the winter months but with lower numbers of mosquitoes. However, in 2014, more than 10,000 mosquito pools were tested in the first 10 of 20 weeks and 2,600 additional mosquito pools were tested in the latter 10 of the 20 weeks, culminating in a season total of 12,608. In 2015, 13,877 pooled mosquito samples were tested between January and the end of December, resulting in 1,269 more pools than 2014.

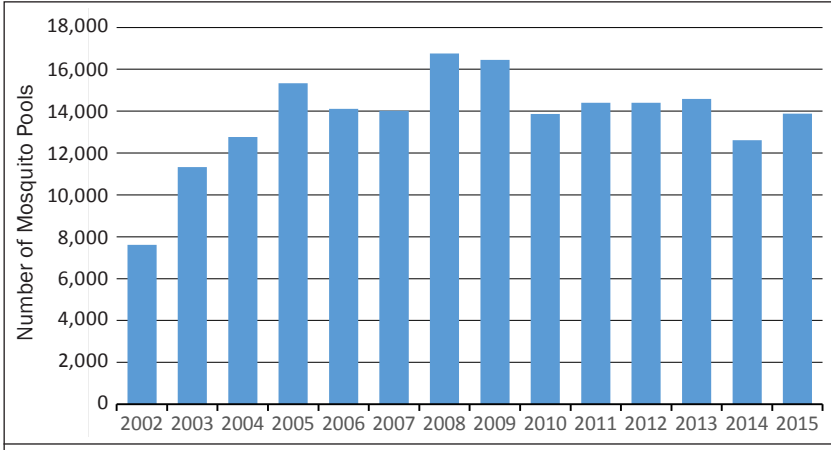


Figure 3. Number of *Culex quinquefasciatus* mosquito pools tested annually for WNV in Harris County, including the city of Houston, Texas, 2002 to 2015.

In HC and Houston, mosquito surveillance collection records and test results were recorded in a database according to weekly calendars of each year (Table 1). A detailed analysis of the virus transmission period, during each of the 14 years of virus outbreaks showed that a peak in the number of confirmed WNV positive mosquitoes occurred in weeks 30 to 32 (July 26-August 15) in 12 of 14 years. However, in 2007, the greatest number of positive WNV mosquito pools occurred later in the year (week 42, October 14-20), while early in 2008 (week 22, May 25-31) as shown in Table 2.

Over the past 14 years, the number of mosquitoes infected with WNV in HC and Houston fluctuated with several high count years, and a few years with very low numbers (Figure 4). The number of WNV positive mosquitoes remained elevated for a number of years and then declined from 2007-2010. The years 2005 and 2006 had high numbers (805 and 838) of WNV positive mosquito pools. Similarly, 2011 had a high number of virus activity with 605 confirmed WNV positive mosquito pools. There was a decline in WNV activity (227) in 2012, followed by a marked decline in 2013 with only 147 WNV positive mosquito pools.

In 2014, the first WNV positive mosquitoes were detected in week 23 (June 6). The numbers steadily increased each week thereafter until reaching 1,286 confirmed WNV positive mosquito pools in a single summer season, far surpassing those of any of the previous 12 years. In the second week of July, more than 100 positive samples were confirmed each week for 7 weeks. The peak of viral activity occurred in week 30 (July 20-26), with a record number of 168 WNV positive mosquito pools. The number of positive pools began declining in late August with a reduction of nearly 50% or less each week until the end of September when only 9 WNV positive mosquito pools were detected and confirmed. Additionally, 7 more were confirmed positive for week 40 on October 3, 2014. The total number of confirmed WNV positive mosquito pools for 2015 was 406, a reduction of more than 800 from 2014.

In 2002, the first detection of WNV positive mosquito pools occurred in the second week of June (week 24, June 9-15). Detection of WNV positive mosquito pools continued over a 20 week period from June to November. The highest number of positives (32) occurred in week 31 (July 28-August 3). In 2003, WNV was detected over 24 weeks from May to November. Week 30 (July 20-26) had the highest number of positive mosquitoes with 64 confirmed infected pools. In 2004, WNV was detected from June to December over a period of 27 weeks. The peak number of positives was 65 in week 30 (July 25-31). In 2005, it was found from May to October, over a 22 week period with a peak number of 137 in August. Although there was a longer mosquito WNV detection period in 2004, the number of positive samples was lower than that of 2005.

In 2006, the mosquito WNV transmission period was the longest of the years studied with a duration of 31 weeks from May 9 to December 6. The peak activity

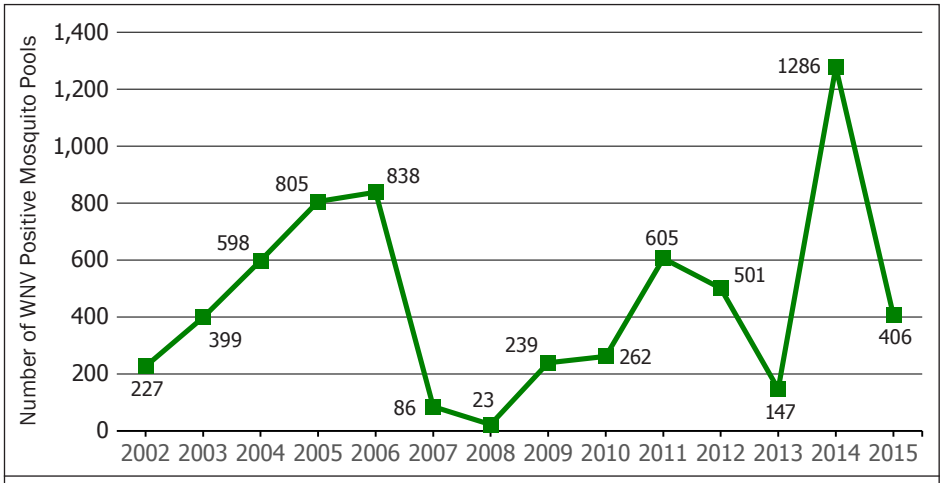


Figure 4. The number of mosquito pools in which mosquitoes infected with WNV were detected in Harris County, including the city of Houston, Texas, 2002 to 2015.

Table 1. Week numbering assignments for collection/test results database purposes relative to calendar months of 2002 to 2015.

| Weeks assigned to calendar months for: 2002, 2003, 2007, 2008, 2013, 2014 | | | | Weeks assigned to calendar months for: 2004, 2005, 2006, 2009, 2010, 2011, 2012, 2015 | | | |
|---|---|---|---|---|---|---|---|
| **Month** | **Weeks** | **Month** | **Weeks** | **Month** | **Weeks** | **Month** | **Weeks** |
| January | 01-05 | July | 27-31 | January | 01-04 | July | 26-30 |
| February | 06-09 | August | 32-35 | February | 05-08 | August | 31-34 |
| March | 10-13 | September | 36-39 | March | 09-12 | September | 35-39 |
| April | 14-18 | October | 40-44 | April | 13-17 | October | 40-43 |
| May | 19-22 | November | 45-48 | May | 18-21 | November | 44-47 |
| June | 23-26 | December | 49-52 | June | 22-25 | December | 48-52 |

of 97 positive pools was confirmed in the week of July 30-August 5 (31st week of 2006). In 2007, mosquito WNV activity was confirmed over a period of 18 weeks from June to November with a peak of 11 positive pools in week 42 (October 14-20).

In 2008, mosquito WNV was detected over a period of 13 weeks between April and October. The peak number of positives was 6 in week 22 (May 25-31). The virus was detected from May to October in 2009, with a high number of 30 positive pools in week 30 (July 26-August 1).

In 2010, the virus activity period extended for 22 weeks from June to December, peaking at 40 positive pools in week 33 (August 10-16). In 2011, WNV in mosquitoes was detected over 24 weeks from May to November with a peak number of 87 positive pools during week 32 (August 7-13). The season extended from May to November for 25 weeks in 2012 with a peak number of 72 positive pools in week 32 (August 5-11). In 2013, the virus was detected from June to November for 19 weeks with a peak of 19 positive mosquito pools in week 32 (August 4-10).

Table 2. Mosquito WNV detection period and weeks with the highest number of positive mosquito pools from 2002 to 2015

| Variable | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|
| Virus Detection Period | Jun-Nov 20 weeks | May-Nov 24 weeks | Jun-Dec 27 weeks | May-Oct 22 weeks | May-Dec 31 weeks | Jun- Nov 18 weeks | Apr-Oct 13 weeks |
| Week No/Peak No. Positives | 31/32 | 30/64 | 30/65 | 32/137 | 31/97 | 42/11 | 22/6 |
| Total No. WNV Confirmed | 227 | 399 | 598 | 698 | 838 | 86 | 23 |
| Variable | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| Virus Detection Period | May-Oct 19 weeks | Jun-Dec 22 weeks | May-Nov 24 weeks | May-Nov 25 weeks | Jun-Nov 19 weeks | Jun-Oct 18 weeks | Jun-Nov 25 weeks |
| Week No/Peak No. Positives | 30/30 | 33/40 | 32/87 | 32/72 | 32/19 | 30/168 | 30/58 |
| Total No. WNV Confirmed | 239 | 262 | 605 | 501 | 147 | 1,286 | 406 |

In 2014, the first confirmed WNV positive mosquito pool was detected on June 6. Beginning in the second week of July (week 28, July 06-12), over 100 positive samples were confirmed each week for 7 weeks. The period of high mosquito WNV risk extended for 18 weeks with a peak total of 168 positive pools during week 30 (July 20-26). The number of positive pools decreased in late August (August 26-29), with a reduction of nearly 50% or less each week until the end of September. Detection of WNV positive mosquito samples continued into October with 15 positive mosquito pools confirmed on October 16, 2014.

The 2015 WNV mosquito season began in June with a confirmation of the first positive mosquito pools on June 16 (week 24), and continued until week 46 in mid-November. The highest number of positive pools (58) was detected in week 30 (July 26–August 1) and closely mirrored the following week (August 2-8) with 54 confirmed WNV positive mosquito pools. The season ended with a total of 406 WNV positive mosquito pools.

The areas of Harris County which were confirmed with mosquito WNV activity in 2013 are shown in Figure 5. Positive areas are highlighted with red stripes and dots. Heaviest concentrations of mosquito WNV activity were in the northern areas with scatterings in the far west, southwest, and southeast quadrants of HC. Areas inside the I-610 Loop were not as involved as in past years, and only 73 of the 268 areas county-wide were confirmed positive with WNV in mosquitoes.

In the viral activity map of 2014 (Figure 6), nearly the entire county was highlighted in red stripes and dots; 235 (87.7%) areas of the 268 surveillance/operational areas. A map of mosquito-borne disease activity for 2015 is shown in Figure 7. The WNV in mosquitoes was detected and confirmed in 138 (51.4%) operational areas. The highest proportion of WNV positive mosquitoes in 2015 were detected in areas in the southwest sectors within the I-610 loop. Other highly infected areas were located in the southwest and far west sections of HC. A cluster of the virus was also detected in 10 areas in Baytown, located in the easternmost sector of Harris County.

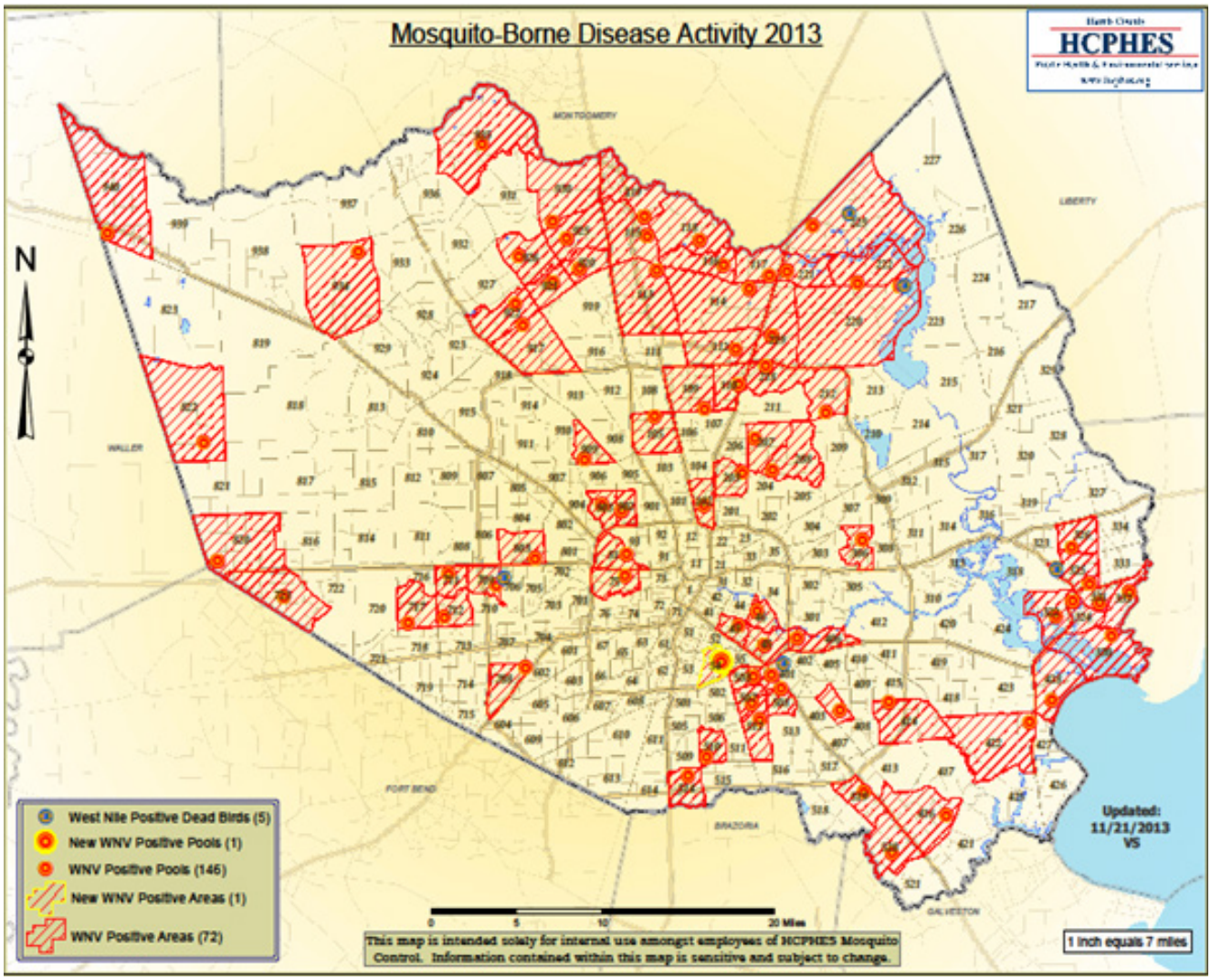


Figure 5. Map of Harris County, Texas, showing 72 areas (27%) with confirmed WNV positive mosquito pools (147) in 2013. Positive areas are highlighted with red stripes and dots.

## Summary

Based on the data collected since WNV's emergence into HC and Houston, mosquito WNV cases typically began in May or June, and declined to low levels in October or November. However, in 2004, 2010, and 2006, the WNV season extended into December. In 2008, it began early in April, and extended until October for a period of only 13 weeks. Six mosquito WNV outbreaks began in May (2003, 2005, 2006, 2009, 2011, 2012), and seven in June (2002, 2004, 2007, 2010, 2013, 2014, 2015). Four ended in October (2005, 2008, 2009, 2014), seven in November (2002, 2003, 2007, 2011, 2012, 2013, 2015) and three in December (2004, 2006, 2010).

The length of the mosquito WNV detection period had no indication of the amount of WNV detected and had no bearing on the number of positive mosquito pools confirmed. In 2014, which had the highest number ever of confirmed positive mosquito pools (1,286), WNV was detected for 18 weeks, matching 2007 which had only 86 positive mosquito pools. The shortest detection period was in 2013, lasting only 13 weeks with 23 WNV positive mosquito pools. The longest period was in 2006 which extended for 31 weeks, resulting in 838 positive pools. Each of the 14 years had a peak of WNV activity during late July and August (weeks 30-33), with the exception of 2007 and 2008 which had the most in week 42 (October) and week 22 (May), respectively.

The distribution pattern of viral activity within the surveillance areas of HC in any given year was equally unpredictable because it differed from year to year. Areas within the I-610 Loop in the heart of Houston figured prominently, providing hot spots of viral activity during

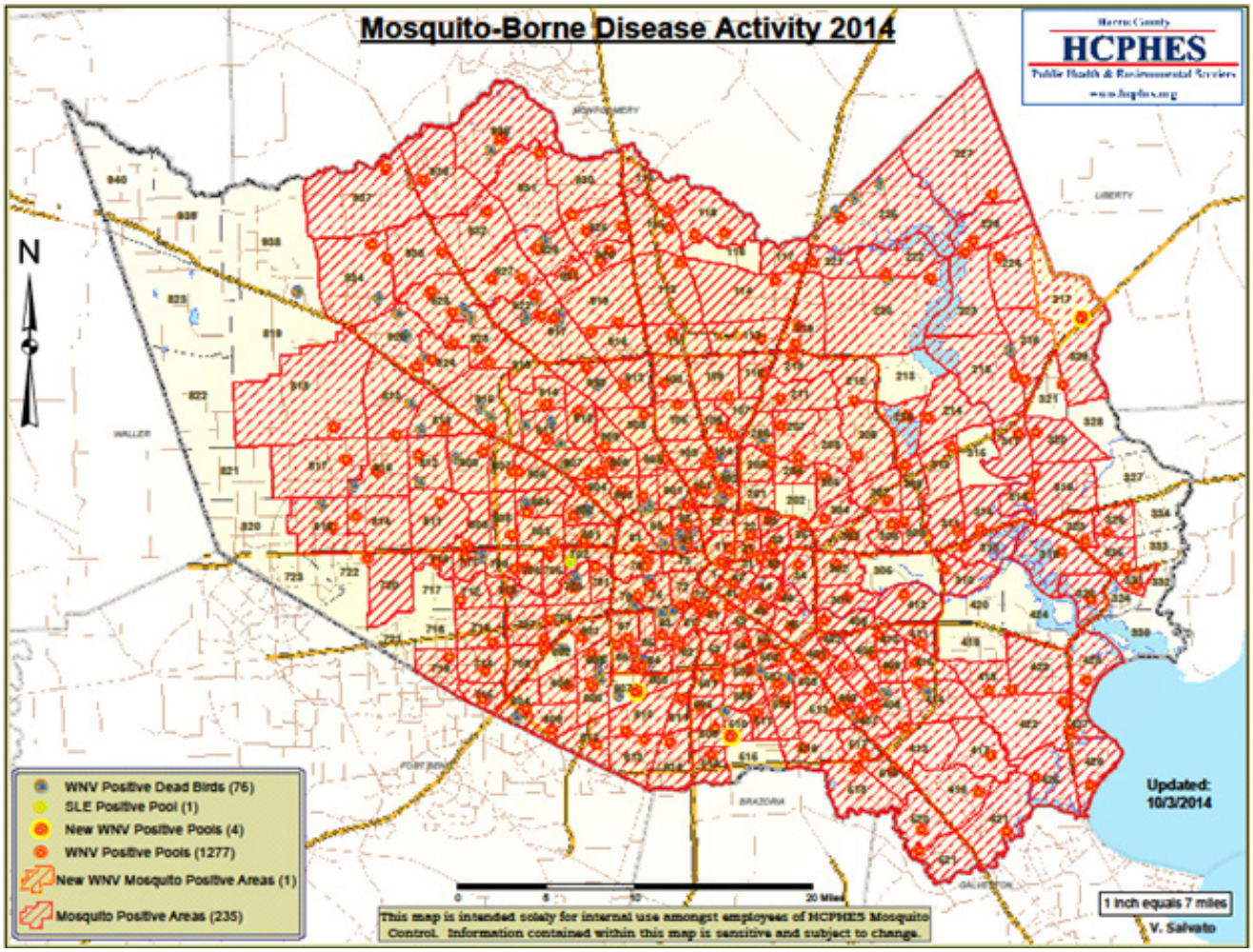


Figure 6. Map of Harris County, Texas, showing 235 areas (87.7%) with confirmed WNV positive mosquito pools (1,286) in 2014. Positive areas are highlighted with red stripes and dots.

10 of the 14 years (2002-2006, 2008, 2009, 2011, and 2014). Four years (2007, 2010, 2012, and 2013) had minimal WNV activity within the I-610 loop but more in the southwest, far west, northwest, and northeast sectors of HC. In 2004, 2005, 2006, 2011, and 2014, there were high numbers of confirmed WNV positive mosquito pools over multiple weeks in areas within the I-610 Loop, as well as northwest and northeast HC that generated multiple numbers per site.

In 2006, 9 areas had between 24 and 67 confirmed samples per area, a season that lasted 31 weeks. In 2014, WNV was much more widespread than in any other of the 14 years. Although the virus was detected in 87.3% of the 268 areas and 1,286 mosquito pools were confirmed positive over a period of 18 weeks, there were only 34 areas with 10 or more confirmed pools during the season. Each of the remaining areas had fewer than 10 confirmed WNV positive mosquito pools.

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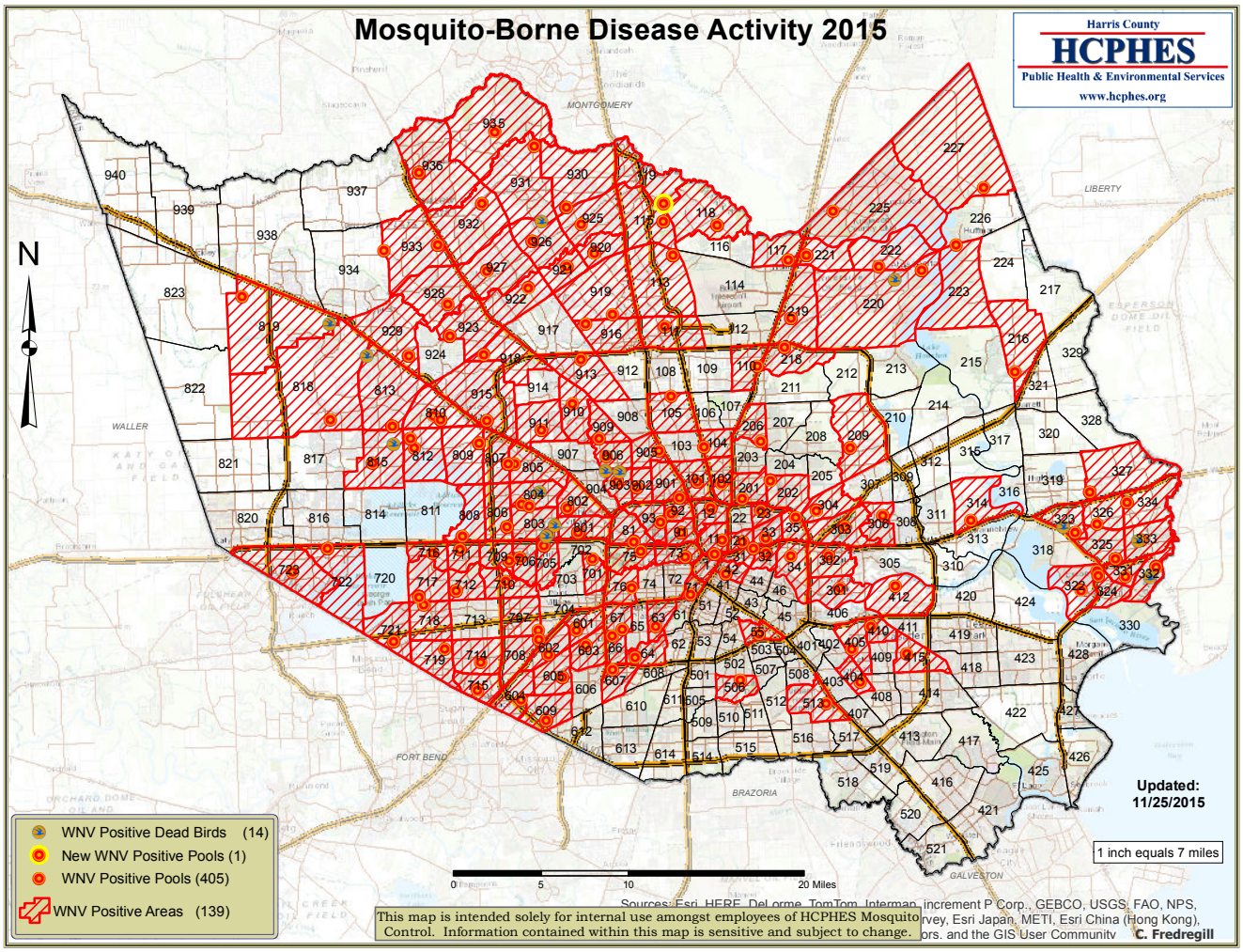


Figure 7. Map of Harris County, Texas, showing 138 areas (51.5%) with confirmed WNV positive mosquito pools (406) in 2015. Positive areas are highlighted with red stripes and dots.


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# A Multiagency Approach to Reducing West Nile Virus Risk in Richmond County, Georgia, in 2015

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R. Chris Rustin, DrPH, MS, REHS

ABSTRACT

The Richmond County Mosquito Control program's mission statement is to incorporate strategies of integrated mosquito control management that are effective, practical, and environmentally safe and protect the health of Richmond County residents, as well as promote public education, in order to prevent large mosquito populations and the diseases that they transmit. To this end, the program coordinates efforts with other county agencies in order to provide better service. This is a small program with limited resources, so in an effort to provide better integrated mosquito management, the mosquito control program and the Phinizy Center for Water Sciences joined efforts to trap mosquitoes at sites across the county, identify the species, and send the mosquitoes off for viral testing. These data help determine locations of disease-carrying mosquitoes so the county can more efficiently control the mosquito populations and reduce the risk of West Nile virus transmission.

Richmond County is located on the Georgia/South Carolina border, about 150 miles (240 km) east of Atlanta and 70 miles (110 km) west of Columbia. According to the US Census Bureau (2015), the county has a total area of 329 square miles; 324 square miles is land and 4.3 square miles (1.3%) is water. Richmond County is in the Savannah River basin.[1]

Augusta is the principal city of the Augusta-Richmond County Metropolitan Statistical Area, which as of 2012 had an estimated population of 580,270,[1] making it the third-largest city and the second-largest metro area in the state after Atlanta. Augusta is located about halfway up the Savannah River on the fall line, which creates a number of small falls on the river. The city marks the end of a navigable waterway for the river and the entry to the Georgia Piedmont area.

The Richmond County Mosquito Control program is a part of the Richmond County Environmental Health office. It is a small program with one full-time and 4 seasonal workers that was established in 1983 in response to the emergence of a large nuisance mosquito problem. Some limited surveillance was done in the county in response to West Nile virus (WNV), but the program worked to create partnerships with other county and local agencies, as well as with the Georgia Department of Public Health (GDPH), with the intent to expand the program into a fully functioning, integrated pest management operation. Some surveillance was done by the state entomologist in response to either complaints or WNV cases beginning in 2004. In 2007, the mosquito control program hired a seasonal mosquito surveillance technician for the year. Because of the benefits to the program associated with mosquito surveillance, in 2014 the Richmond County Mosquito Control program joined forces with the Phinizy Center for Water Sciences, a local nonprofit water quality research organization in order to trap mosquitoes at sites across the county and identify them to species. These data helped determine locations of disease-carrying mosquitoes during the 2015 WNV season, allowing mosquito control to prioritize their control efforts, reducing the risk of viral transmission in Richmond County.[2] The GDPH supported these efforts with free mosquito identification and training classes for the researchers at Phinizy Swamp, as well as providing use of the GDPH emergency mosquito surveillance trailer with its complement of mosquito surveillance equipment.[3]

## The Phinizy Center for Water Sciences

The Phinizy Center for Water Sciences was established to provide leadership to balance sustainable watersheds and economic vitality through solutions-based research, education, and public involvement (http://phinizycenter.org). The Phinizy Center manages the Phinizy Swamp Nature Park, a 1,100-acre nature park in the city of Augusta. The park contains wetlands and woodlands and has a campus for water research and environmental education. As the wetlands at Phinizy Swamp Nature Park obviously have the potential to contribute to mosquito problems in Richmond County, the scientists at the Phinizy Center are intimately involved in efforts to address the risks.

West Nile virus is a mosquito-borne viral pathogen that was introduced into the United States in 1999. Within 4 years following its initial detection in New York, WNV was detected in states from the East and West coasts as well as in Mexico and Canada.[4]

West Nile virus is maintained in birds. It occasionally infects humans who are bitten by mosquitoes that have been feeding on birds. Most people (approximately 80%) infected with WNV do not develop symptoms. About one in five infected people experiences a milder illness, often termed "West Nile fever," characterized by fever, headache, muscle weakness or myalgia, arthralgia, and sometimes rash. Less than one percent of persons infected with WNV develop neurologic illness (West Nile neurologic disease (WNND)) in the form of meningitis, encephalitis, or possibly acute flaccid paralysis. Approximately 3% to 15% of WNND cases are fatal. Risk of WNND is associated with increasing age and the presence of underlying medical conditions.

Table 1. Human Cases of WNV: Georgia statewide and Richmond County, 2001-2015*

| Year | Georgia Statewide | Richmond County |
|---|---|---|
| 2001 | 6 | |
| 2002 | 36 | |
| 2003 | 55 | |
| 2004 | 23 | 2 |
| 2005 | 24 | 1 |
| 2006 | 11 | |
| 2007 | 55 | 3 |
| 2008 | 12 | |
| 2009 | 6 | |
| 2010 | 14 | |
| 2011 | 25 | |
| 2012 | 117 | 4 |
| 2013 | 20 | 1 |
| 2014 | 13 | 2 |
| 2015 | 15 | 3 |

*Data from GDPH Arboviral Surveillance and Richmond County Mosquito Control records.

The presence of WNV in Georgia was first confirmed in July 2001 when an American crow from Lowndes County tested positive for the virus. Since then, human cases, equine cases, positive birds, and positive mosquito pools have been detected every year within the state.

Since 2012, human cases have been reported every year in Richmond County (Table 1). Since mosquito control is a small program, it was determined that an interagency approach was needed to better target mosquito control to reduce mosquito populations and reduce the risk of WNV transmission. High risk areas are defined as areas with a human WNV case or a WNV positive mosquito pool.

## Methods

In 2015, Richmond County Mosquito Control created a 5-step action plan for responding to a potential WNV outbreak:

Step 1: Identify a 2-block area on all sides of the high risk area without identifying case location (Figures 1 and 2). For human cases, the street name is obtained from the GDPH District Epidemiologist. (Note: The state of Georgia is divided into 18 public health districts of varying size based on population.)

Step 2: Mosquito surveillance and identification is provided by the Center for Water Science at Phinizy Swamp. When a WNV positive case is detected, trapping equipment will be positioned to establish 2 locations on each side of the positive site. Traps will be set every 2 weeks, and selected species will be sent for virus testing after identification. This will continue until the end of the year.

Step 3: Realign the spray areas to include WNV positive locations. Use a thermal fogger in overgrown yards and unoccupied houses. If any mosquito pools test positive for WNV, reevaluate the spray areas and patterns. Add an additional spray event in the early morning to control daytime biters (Table 2).

Step 4: Conduct a neighborhood survey (Figure 3) to locate any other mosquito habitats that can be eliminated or treated, working with code enforcement, animal control officers, and deputies from the marshalls' department to write citations if necessary. Once completed, reevaluate the spray areas with any new information and make any necessary adjustments.

Step 5: Continue the public awareness program. This includes media events, health fairs, and a family emergency planning day.

The non-WNV positive areas continued to be sprayed as needed and were monitored for other complaints. Surveillance in these areas is done every 2 weeks.

Table 2. Spray and Trapping Schedule

| Date | Procedure |
|---|---|
| 8/25/2015 | First morning spray (7:45 to 8:45) |
| 8/27/2015 | Evening spray (6:30 to 7:30) |
| 8/31/2015 | Baseline trapping at 4 selected sites |
| 9/1/2015 | Morning spray |
| 9/3/2015 | Evening spray |
| 9/4/2015 | Mosquito pools from baseline sent for testing* |
| 9/8/2015 | Morning spray |
| 9/10/2015 | Evening spray |
| 9/15/2015 | Morning spray |
| 9/15/2015 | First trapping of regular series (every 2 weeks) |
| 9/17/2015 | Evening spray |
| 9/17/2015 | Mosquito pools from regular series sent for testing* |
| 9/22/2015 | Morning spraying cancelled due to rain |
| 9/24/2015 | Evening spray |

*Virus testing conducted by University of Georgia College of Veterinary Medicine as part of the Southeastern Cooperative Wildlife Disease Study (http://vet.uga.edu/scwds).

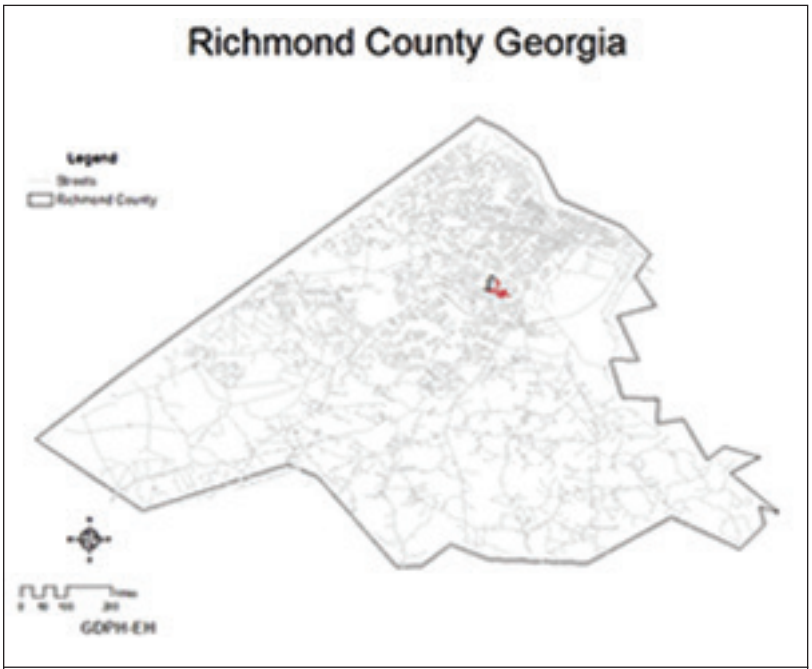


Figure 1. Map of Richmond County, Georgia, showing the high risk area of concern.

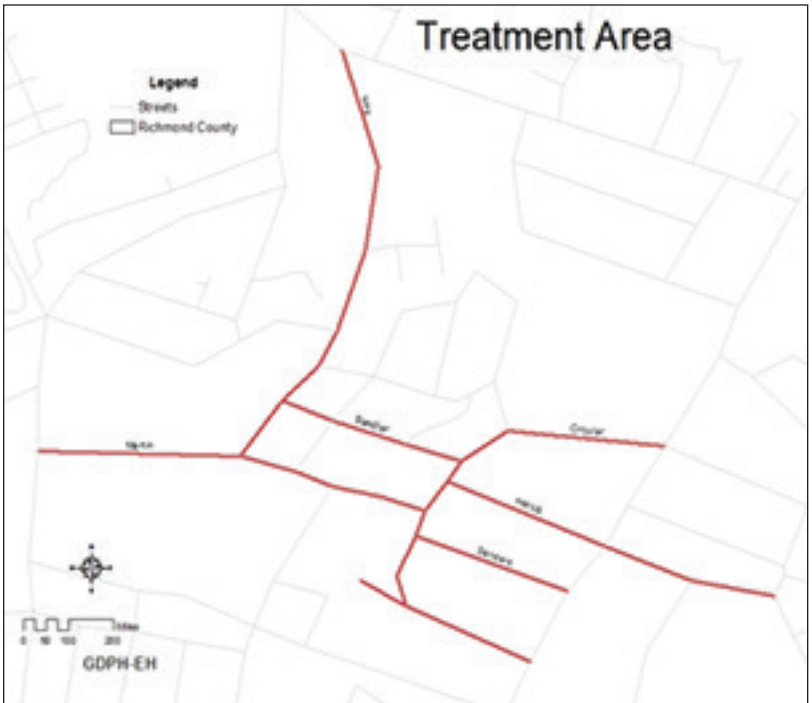


Figure 2. Area specifically treated following neighborhood survey.

## Results

Typically, Richmond County has very few WNV human cases. The first human case was reported in 2004; the first case in Georgia was reported in 2001. However, since 2012, there have been cases reported every year in Richmond County. Mosquito surveillance had been a missing component of the Richmond County Mosquito Control Program. The creation of a partnership with the Phinizy Center for Water Sciences has resulted in better focused mosquito control efforts. In 2015, the first WNV case in Richmond County was reported in July, and a second case reported soon after. A third case was reported the following month. All 3 cases were less than 10 miles from one another. *Culex quinquefasciatus*, Georgia's primary WNV vector, flies approximately a half mile in search of a blood meal. In an effort to reduce the risk of WNV in the area between and around the 3 case sites, Richmond County Mosquito Control implemented their 5-step response program.

The 2015 area surveillance in the high risk area (Figure 2) collected 12 different mosquito species, including *Culex quinquefasciatus* (Table 3). Twenty-five mosquitoes sampled from one pool tested positive for WNV (Table 4). Although the number of WNV cases in Richmond County has historically not been high, the ability to better target mosquito control has helped reduce risk of disease transmission.

## Conclusions

Although complaints by residents can provide some information on the presence of mosquito problems in a given area, surveillance allows the targeting of areas where vector populations are high. Surveillance and viral testing also provides a means of determining the effectiveness of control efforts. Although some level of surveillance was done in Richmond County almost every year starting in 2004, it was primarily performed once a month. More frequent surveillance is needed to support targeted mosquito control efforts.

The collaboration with the Phinizy Center has changed mosquito control operations and saved Richmond County money. Identifying areas of the county with disease-carrying species helps to accomplish the primary mission of aiding public health by reducing the number of vector species and reducing the risk of disease transmission.

The current goal is to increase public education programs with civic clubs, churches, schools, homeowners' associations, and public events. Outreach to the public

Date and time: October 20, 2015 10 AM to 3 PM

People involved:

- 5 from Mosquito Control
- 1 from Environmental Health as observer
- 1 from Center for Water Sciences (trapping and identification)
- 5 from Augusta/Richmond County Code Enforcement
- 3 from Richmond County Marshal's department
- 6 from Richmond County Sheriff's department
- Animal control was on standby due to personnel shortage.

142 Properties surveyed (Figures 1, 2):

- 32 houses on Bandler Rd
- 49 houses on Circular Dr
- 15 houses on Harold Dr
- 17 houses on Sanders Rd
- 26 houses on Martin Rd
- 3 houses on Ivey Rd

Age of houses in survey area:

- 80% of the houses in the survey area were built between 1944 and 1952.
- All houses are located within a 180-acre area divided equally on both sides of a major 4 lane highway.
- All houses on both sides are similar in age and maintenance.
- Construction materials range from brick to lap board and T-11. Most carports are aluminum.
- Almost all houses have crawl spaces which are well known as mosquito habitats.

Figure 3. Neighborhood survey following surveillance and treatment of area of concern.

Table 3. Mosquito Surveillance Data From a High Risk Area

| Species | 08/31/15 | 09/02/15 | 09/09/15 | 09/23/15 | 10/14/15 | Species Total |
|---|---|---|---|---|---|---|
| *Aedes albopictus* | 115 | 113 | 88 | 98 | 65 | 479 |
| *Aedes vexans* | | 1 | 16 | 2 | | 19 |
| *Anopheles crucians complex* | | | | | 4 | 4 |
| *Anopheles quadrimaculatus* | | 2 | 2 | 13 | 4 | 21 |
| *Culex erraticus* | | 27 | | 2 | | 29 |
| *Culex nigripalpus* | | | 1 | 2 | | 3 |
| *Culex quinquefasciatus* | 6 | 19 | 2 | 147 | 38 | 212 |
| *Culex salinarius* | | 69 | 30 | 3 | 779 | 881 |
| *Ochlerotatus triseriatus* | 1 | 4 | | 3 | 8 | 16 |
| *Orthopodomyia signifera* | | | | 2 | | 2 |
| *Psorophora columbiae* | | 1 | | 2 | 2 | 5 |
| *Psorophora ferox* | | | | 1 | | 1 |
| Grand Total | 122 | 236 | 139 | 275 | 900 | 1,672 |

Table 4. Richmond County Mosquito Surveillance Results, 2004-2015

| Year | WNV Test Results | | Yearly Total |
|---|---|---|---|
| | Negative | Positive | |
| 2004 | 17 | | 17 |
| 2006 | 373 | | 373 |
| 2007 | 1,395 | 7 | 1,402 |
| 2008 | 1,906 | | 1,906 |
| 2009 | 841 | | 841 |
| 2010 | 212 | | 212 |
| 2011 | 384 | | 384 |
| 2012 | 4,992 | | 4,992 |
| 2013 | 2,272 | | 2,272 |
| 2014 | 111 | | 111 |
| 2015 | 747 | 25 | 772 |
| Grand Total | 13,250 | 32 | 13,282 |

is the best method of reducing mosquito habitats for the better health of the citizens of Richmond County, especially with the recently identified potential risks presented by the Zika virus.

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# Protection of Military Personnel Against Vector-Borne Diseases: A Review of Collaborative Work of the Australian and US Military Over the Last 30 Years

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ABSTRACT

Australian and US military medical services have collaborated since World War II to minimize vector-borne diseases such as malaria, dengue, and scrub typhus. In this review, collaboration over the last 30 years is discussed. The collaborative projects and exchange scientist programs have resulted in mutually beneficial outcomes in the fields of drug development and personal protection measures against vector-borne diseases.

The role of the Royal Australian Army Medical Corps and the US Army Medical Department is to provide the best medical care for members of the Australian and US armed forces. The task to provide protection against vector-borne diseases such as malaria, dengue, arboviruses, and others is undertaken by various groups in both countries. In Australia, this work has been undertaken by a small group of medical officers and scientists at the Army Malaria Research Unit (AMRU), which became the Army Malaria Institute (AMI),[1-6] and in the United States, the Walter Reed Army Institute of Research (WRAIR) in Forest Glen, MD, and its overseas laboratories.[7]

Collaboration between the United States and Australia was important during World War II in the Pacific. The work conducted between 1941 and 1945 by the Australian Land Headquarters Medical Research Unit is described in detail by LTC A. W. Sweeney in his book, *Malaria Frontline*.[8]

LT Doug Waterhouse, Royal Australian Army Medical Corps, conducting mosquito repellent tests at Lalipipi village in Papua New Guinea during World War II (1943).

During the Vietnam War, many cases of vector-borne disease were observed in Australian, United States, and other Allied defense personnel. The medical resources and personnel of both countries collaborated to optimize and evaluate measures against diseases. The high number of malaria cases in Australian soldiers in Vietnam in 1965 resulted in the establishment in 1966 of the 1 Malaria Research Unit, under the direction of Professor Robert H. Black at the University of Sydney. This unit was moved to Ingleburn, 35 km southwest of Sydney, New South Wales, in 1974.[1]

In 1985, LTC Sweeney visited medical research units in the United States and fostered a formal collaboration between AMRU and US military scientists. One of the first collaborations involved field testing of new mosquito repellents and permethrin treated military uniforms at Cowley Beach, northern Queensland, Australia. This field trial was conducted by 4 scientists from the Letterman Army Institute of Research, Presidio of San Francisco, and AMRU. The study showed that a combination of wearing permethrin treated battle dress uniforms and repellents containing deet provided the best protection against mosquitoes.[9] A subsequent field trial at the same site in 1990 conducted by AMRU and the US Department of Agriculture compared methods of protection against trombiculid larvae (chiggers). This study showed that permethrin treated uniforms provided protection against mites that cause scrub itch.[10]

Mention of a commercial product does not constitute an endorsement of the product by the Australian Defence Force or US Department of Defense.

## Exchange Scientists

### Medical Officers in Malaysia

Australian medical officers first worked in Malaysia at the US section of the Institute of Medical Research (IMR) in Kuala Lumpur in the early 1980s. They collaborated with US Army and Malaysian medical officers on protection against scrub typhus and snake envenomation. The joint studies conducted showed that doxycycline was an effective prophylaxis for scrub typhus,[11] and field surveillance showed that disease in Malaysia was underreported.[12,13]

### Exchange Scientists in Thailand and Australia

In 1988, the US section of IMR Malaysia closed and an exchange was established with the Armed Forces Research Institute for Medical Sciences (AFRIMS) in Bangkok, Thailand, and the Australian AMRU. Between 1989 and 1992, MAJ M. D. Edstein from AMRU worked at AFRIMS primarily on preclinical drug development and clinical evaluation of standard and new antimalarial drugs. During this 3-year period, MAJ Edstein and US Army and Thai Army collaborators researched new antimalarial compounds using nonhuman primates for causal prophylactic and radical curative activity. Of these studies, WR182393, a non-8-aminoquinoline guanylhydrazone, exhibited both causal prophylactic and radical curative properties in the rhesus monkey (*Macaca mulatta*)/*Plasmodium cynomolgi* test model, a vivax malaria-like model.[14] However, using the same model, the prophylactic combination of proguanil plus sulfamethoxazole was found not to be causally prophylactic.[15] Additionally, the proguanil analog WR250417 (also known as PS-15) was shown to extend the prepatent period of *P cynomolgi* from 8.5 days to 18.3 days in drug-treated monkeys, but did not prevent a primary infection.[16]

For clinical studies, new high performance liquid chromatographic (HPLC) methods were developed for the analysis of antimalarial drugs such as quinine,[17] halofantrine,[18] mefloquine-sulfadoxine-pyrimethamine,[19] and ciprofloxacin.[20] These HPLC methods were used to characterize the pharmacokinetic-pharmacodynamic interaction of mefloquine in resistant *P falciparum* malaria on the Thai-Burma/Myanmar* border,[21] assess the efficacy of halofantrine in treating Thai patients who failed mefloquine chemoprophylaxis,[22] evaluate the potential of ciprofloxacin in treating drug-resistant falciparum malaria,[23] assess the effect of food on the disposition of halofantrine in treating falciparum malaria[24] and determine the effectiveness of high-dose mefloquine in treating multidrug-resistant falciparum malaria.[25]

*The country of Burma was renamed Myanmar in 1989.

MAJ Michael Edstein of the AFRIMS Department of Immunology (on assignment from the Australian Army Malaria Institute), and MAJ Catherine (Dahlem) Smith, US Army, Chief of the Department of Veterinary Medicine, team up to administer an antimalarial drug to a monkey in a pharmacokinetic study (1990). Photo courtesy of AFRIMS photograph archives.

At the time of those studies, mefloquine was the treatment of choice for uncomplicated multiresistant falciparum malaria. A standard dose of 15 mg/kg of mefloquine became ineffective in treating acute falciparum malaria in an area with deteriorating multidrug resistance on the Thai-Myanmar border. By increasing the mefloquine dose to 25 mg/kg, the clinical and parasitologic responses were significantly more rapid with high dose mefloquine compared with the standard dose.[26] The failure rate by day 28 of follow-up was 40% and 9% with 15 mg/kg and 25 mg/kg of mefloquine respectively. Adverse events were dose-related and included dizziness, anorexia, nausea, vomiting, and fatigue.

Mefloquine in combination with sulfadoxine and pyrimethamine (MSP) at a single dose of 15/30/1.5 mg/kg, respectively, also became ineffective. In 1985-1986, MSP cured over 98% of 5,192 patients with falciparum malaria on the Thai-Myanmar border. Four years later, the efficacy of MSP in 395 patients at the same location had declined to 71%. In these patients, the mean serum mefloquine concentration at the time of first recrudescence was 638 (546-730) ng/mL, a value previously associated with successful treatment. These findings suggested that *P falciparum* had rapidly developed resistance to mefloquine, despite the addition of sulfadoxine and pyrimethamine. The recommendation was to abandon the MSP combination.[21] The development of resistance to mefloquine highlighted the urgent need to evaluate new antimalarial drugs such as halofantrine. The recommended regimen of halofantrine was 3 doses of 500 mg

(1,500 mg total or 24 mg/kg) at 6-hour intervals given with food to enhance drug absorption. However, this halofantrine regimen was found to be ineffective in treating 30% (7/23) of Thai soldiers who showed slide-positive results for malaria while receiving mefloquine chemoprophylaxis.[22] The serum halofantrine concentrations were higher in patients cured by halofantrine compared with those who failed treatment. These observations suggested that the 24 mg/kg regimen of halofantrine was not optimal for the treatment of multiple drug-resistant falciparum malaria in Thailand. A higher dose of halofantrine (72 mg/kg) was more effective in treating uncomplicated falciparum malaria with a failure rate of 15%, but evidence of possible cardiotoxicity was observed and required investigation.[26] Studies by other investigators led to the demise of halofantrine due to cardiotoxicity.

MAJ Stephen Frances (ADF) treating Royal Thai Army uniforms with permethrin from a back pack aspirator in Sisaket Province, Thailand, 1992.

In 1992, MAJ Edstein was replaced at AFRIMS by MAJ S. P. Frances, an entomologist, who worked on personal protection measures against malaria vectors, and biology of the vectors of scrub typhus. While at AFRIMS, Frances conducted laboratory and field evaluations of repellents and toxicants against mosquito vectors of malaria and mite vectors of *Orientia tsutsugamushi*.[27-33] He also worked on vectors of scrub typhus, resulting in the establishment of colonies of *Leptotrombidiun deliense* (mites) naturally infected with *O tsutsugamushi*, and improved understanding of the ecology of mites, rodent hosts, and the pathogen that causes scrub typhus in Thailand.[34-44]

MAJ Stephen Frances (AMI), Dr Nigel Beebe (University of Technology Sydney, Australia), MAJ Mustapha Debboun (WRAIR) and Senior COL Nguyen van Dung (Vietnam Peoples Army), at Cowley Beach Training Area, northern Queensland, Australia, during mosquito repellent trials in 2001.

During the same time (1992-1995), LTC G. D. Shanks worked at AMRU in Australia. He worked closely with MAJ Edstein, who had returned to Australia, on development of antimalarial drugs. A number of valuable findings during this time included several clinical trials in Papua New Guinea.[45-48]

## Collaborative Projects

Collaboration between AMI and US military scientists has continued. In the 1990s, evaluation of repellent active ingredients deet, AI3-37220, and CIC4,* along with personal protection measures against mosquitoes was undertaken. In 2001, an evaluation of Australian and US repellents was conducted in Australia at Cowley Beach by the AMI with US Army MAJ M. Debboun from WRAIR. The study compared the protection provided by commercial and military repellent on human volunteers.[49] This collaboration continued with evaluation of additional active ingredients in the laboratory and field,[50] as well as field evaluation of a low profile US bednet in Papua New Guinea.[51] The prototype bednet that was tested has been in use by US military personnel for more than a decade.[52] More recently, 3 books on repellents and personal protection measures used by civilian and military personnel were edited by US Army and Australian Defence Forces entomologists.[53-55]

*deet (diethylmethyl benzamide); AI3-37220 (1-(3-cyclohexen-1-cabonyl)-2-methylpiperidine); CIC-4 (2-hydroxomethylcyclohexl) acetic acid)

Financial support from the Defence Warfighters Program of the Armed Forces Pest Management Board to AMI in 2008, allowed evaluation of Australian military shirt fabrics treated with permethrin to be tested to determine protection against mosquito bites of malaria and dengue vectors.[56,57]

Low profile bednet developed at WRAIR and tested in Bougainville, Papua New Guinea, in 1999.

## Drug Development

The development of mefloquine as an antimalarial drug was reviewed by Shanks.[58] The constraints of shrinking military and civilian budgets for development of antimalarial drugs highlighted the need to continue to conduct collaborative development of drugs. Despite this, collaborative research to develop new antimalarial drugs between the two nations has continued.

From 1998-2011, exchange scientists from WRAIR undertook collaborative evaluation of the new antimalarial drug tafenoquine (formerly known as WR238605 or etaquine) for malaria prevention and in vitro studies into artemisinin induced dormant ring-stages of *P falciparum* as a plausible explanation for recrudescence. In 1998, a field study of tafenoquine was conducted in Ubon Ratchatani province, Thailand, with Thai soldiers and collaborators from Australia, United States, and Thai military.[59] The major focus of the study was to determine the safety, tolerability, efficacy, and pharmacokinetics of tafenoquine following an oral loading dose of 400 mg daily for 3 days and monthly administration of 400 mg for 5 consecutive months.[59] In participants completing the follow-up period (96 tafenoquine and 91 placebo recipients), there were 22 *P vivax*, 8 *P falciparum*, and one mixed infection. With the exception of one *P vivax* infection in the tafenoquine group, all infections occurred in placebo recipients, giving tafenoquine a protective efficacy of 97% for all malaria, 96% for *P vivax* malaria, and 100% for *P falciparum* malaria. The soldier in the tafenoquine group who developed malaria during the study had a lower plasma tafenoquine concentration of 40 ng/mL at the time of diagnosis, which was approximately 3-fold lower than the trough concentrations of the other soldiers who were protected from infection by tafenoquine.[60] The phase II study revealed that monthly tafenoquine was safe, well tolerated, and highly effective in preventing *P vivax* and multidrug-resistant *P falciparum* malaria in Thai soldiers during 6 months of prophylaxis. This study was the first investigation of tafenoquine in Southeast Asia and in protecting volunteers from both *P vivax* and *P falciparum* malaria.

LTC Pamornwan Singsawat, Royal Thai Army, and LTC Douglas Walsh (AFRIMS) interview potential subjects in a joint malaria prophylaxis drug study among Thai soldiers in Ubon Ratchathani (1998). Photo courtesy of AFRIMS photograph archives.

To assist in the development and evaluation of tafenoquine, a rapid and sensitive HPLC method for tafenoquine was developed by CPT D. A. Koscisko, US Army, during his assignment to AMI from 1999-2001. With this method, the population pharmacokinetics of tafenoquine was characterized in Thai soldiers who participated in the phase II study.[61,62] A one-compartment model was found best to describe the pharmacokinetics of tafenoquine after oral administration. The drug is widely distributed to body tissues with a high apparent volume of distribution and a lengthy elimination half-life of 16.4 days, suitable for weekly prophylaxis.

LTC D. E. Kyle, US Army, established the WRAIR laboratory at AMI in 2001. He collaborated in studies of the drug Artimisone, which showed it was more effective than artemisinin drugs in curing *P falciparum* in *Aotus* monkeys.[6,63,64] He has continued collaboration with AMI in his role as a professor at South Florida University with studies of the role of gene amplification and expression that induces resistance in *P falciparum*.[65-68]

In February 2004, LTC Kyle returned to the United States and was replaced at AMI by MAJ Mike O'Neil. From 2004 to 2006, he participated in the assessment of the pharmacodynamics and pharmacokinetics of the novel dihydrofolate reductase inhibitor, JPC2056, and its principal active metabolite JPC2067 in cynomolgus monkeys using an in vivo-in vitro (ex vivo) model.[69] In a 2-phase crossover design, cynomolgus monkeys were administered multiple doses (20 mg/kg daily for 3 days) of JPC2056. Plasma samples collected from treated monkeys were assessed for ex vivo antimalarial activity against *P falciparum* lines having wild-type (D6), double-mutant (K1) and quadruple-mutant (TM90-C2A) DHFR-thymidylate synthase (TS) and a *P falciparum* line transformed with a *P vivax* dhfr-ts quadruple-mutant allele (D6-PvDHFR). Plasma JPC2056 and JPC2067 concentrations were measured by LC-mass spectrometry. The mean inhibitory dilution ($ID_{90}$) of monkey plasma at 3 hours after the last dose against D6, K1, and TM90-C2A was 1613, 1120, and 1396, respectively. Less activity was observed with the same monkey plasma samples against the D6-PvDHFR line, with a mean $ID_{90}$ of 53. Geometric mean plasma concentrations of JPC2056 and JPC2067 at 3 hours after the last dose were 150 and 17 ng/mL, respectively. The elimination half-life of JPC2056 was shorter than its metabolite after both regimens (6.6 versus 11.1 hours). The high ex vivo potency of JPC2056 against *P falciparum* DHFR-TS quadruple-mutant lines provides optimism for the future development of JPC2056 as a therapeutic agent.

In 2006, LTC N. Waters (US Army) was assigned to the WRAIR laboratory at AMI. He participated in a major AMI activity and Australian Government Pacific Malaria Initiative assisting in malaria eradication efforts in the Solomon Islands and Vanuatu.[70] The Drug Resistance and Diagnostics department of AMI collaborated with LTC Waters on studies of the molecular assessment of parasite drug resistance.[71] They found that *P falciparum* from both Solomon Islands and Vanuatu had high levels of resistance to Chloroquine[72] and Fansidar.[73] LTC Waters was next assigned to the US Military Academy, West Point, NY, in 2011, and has brought cadets to Australia each year from 2011-2015 to work in the AMI laboratories.

## The Future

After more than 20 years of having US Army officers working in Australia at AMI, the exchange program has lapsed due to nonavailability of those officers. However, the collaboration between the 2 countries continues, especially in the fields of entomological research, drug development, and pharmacology. With the continued meager funding of some fields of medical research and different priorities within the US and Australian Defence Forces, continued collaboration is important to continue to conduct valuable research on a variety of vector-borne diseases. The effect of malaria, dengue, and scrub typhus have remained focal for both countries, and collaborative research will continue to minimize the impact of these diseases on military personnel and civilians alike.

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# Emerging Tick-borne *Rickettsia* and *Ehrlichia* at Joint Base Langley-Eustis, Fort Eustis, Virginia

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ABSTRACT

Four species of ticks known to parasitize humans (Amblyomma americanum (lone star tick), Dermacentor variabilis (American dog tick), Amblyomma maculatum (Gulf Coast tick), and Ixodes scapularis (black-legged tick)) were collected at Joint Base Langley-Eustis, Fort Eustis, Virginia during 2009. These ticks were tested individually (adults and nymphs) and in pools of 15 (larvae) for pathogens of public health importance within the genera: Rickettsia, Borrelia, and Ehrlichia, by quantitative real-time polymerase chain reaction (qPCR) assays and, where appropriate, multilocus sequence typing (MLST). Of the 340 A americanum ticks tested, a minimum of 65 (19%), 4 (1%), 4 (1%), and one (<1%) were positive for Rickettsia amblyommii, B lonestari, E ewingii and E chaffeensis, respectively. One of 2 (50%) A maculatum ticks collected was found to be positive for R parkeri by MLST and qPCR analyses. All 33 D variabilis ticks were negative for evidence of rickettsial infections. Likewise, no pathogenic organisms were detected from the single Ixodes scapularis tick collected. Pathogenic rickettsiae and ehrlichiae are likely emerging and cause under-recognized diseases, which threaten people who live, work, train, or otherwise engage in outdoor activities at, or in the vicinity of, Fort Eustis, Virginia.

Rickettsiae and related ehrlichial organisms are obligate intracellular bacteria carried by mites, fleas, ticks, and lice and are the agents of numerous tick-borne diseases found in Virginia, such as Rocky Mountain spotted fever (*Rickettsia rickettsii*), Tidewater spotted fever (*Rickettsia parkeri*), Human monotropic ehrlichiosis (*Ehrlichia chaffeensis*), and Ewingii ehrlichiosis (*Ehrlichia ewingii*). These and other rickettsial diseases have affected military activities and public health throughout the world for more than 2,000 years.[1] Rickettsial diseases, generally incapacitating and sometimes fatal, are frequently unrecognized or misdiagnosed. If recognized early, they can be treated effectively with antibiotics such as doxycycline, the treatment of choice. Delayed treatment is often associated with a more serious disease outcome, often with complications.[1]

In the United States, there are many tick-borne rickettsiae, most of which belong to the spotted fever group of rickettsiae (SFGR). Among them are *R rickettsii*, *R parkeri*, *Rickettisa montanensis*, and *Rickettsia amblyommii*. The first two are known to be pathogenic to humans and the latter two have limited evidence suggesting possible pathogenicity.[2] Over the past few decades, rickettsiology has undergone significant changes and many new and some previously characterized rickettsiae have been found to be pathogenic.[2,3] As of 2012, 26 *Rickettsia* species with validated and published names have been reported, the vast majority of which are considered tick-borne rickettsiae.[2]

For most of the 20th century, *R rickettsii*, the causative agent of Rocky Mountain spotted fever, was considered the only tick-borne rickettsial agent pathogenic to humans in the Americas. Rocky Mountain spotted fever (RMSF) has been consistently described as a potentially fatal disease. In the early 20th century, 63% of RMSF diagnosed patients from Montana died from the disease.[4] In the late 1940s, antimicrobial therapy was developed for RMSF[4] and doxycycline is now considered the drug of choice for all tick-borne rickettsial diseases in children and adults.[5] While the fatality rate of RMSF has diminished to 1.4% in the United States in the 21st century, it is higher in South American countries (greater than 20%) despite therapy.[4,6] One of the reasons for the fatalities due to RMSF is the difficulty correctly diagnosing the rickettsiosis. Diagnosis of RMSF is problematic due to nonspecific signs and symptoms associated with the disease, which include fevers, headaches, rashes, and the lack of commercially available species-specific assays.[2] Recently there has been an increase in reported RMSF cases in the United States. Only 495 cases were reported to the Centers for Disease Control and Prevention (CDC) in 2000,[7] but 2,288 cases were reported in 2006 and 2,016 in 2007, marking the highest recorded levels in over 80 years.[8] However, most of these cases

have been described as suspect RMSF cases (ie, clinical presentation and a single serum positive test which is group- but not species-specific). The prevalence of the SFGR antibody is known to exist in about 10% of the US population.[9] Thus, the presence of a single positive SFGR-specific serological assay will not specifically diagnose RMSF. Since the assay is nonspecific, the positive serologic reaction could represent an infection with another SFGR pathogen (eg, *R parkeri*, *R akari*) or a rickettsia of unknown pathogenicity (eg, *R amblyommii*, *R montanensis*). Thus, the lower fatality rates associated with RMSF may actually be due to the misdiagnosis of other rickettsioses with lower fatality rates than RMSF.

Tidewater spotted fever, also known as *Rickettsia parkeri* rickettsiosis or American boutoneuse fever, has been a recently described human disease even though the causative agent, *R parkeri*, has been known since its isolation in 1937. Ralph Robinson Parker isolated *R parkeri* from *Amblyomma maculatum*, commonly known as the Gulf Coast tick. *R parkeri* was considered a nonpathogenic rickettsia and received little attention until 2004, when the first case of *R parkeri* human infection, which was similar to yet distinct from RMSF, was reported.[3,10] A second case of *R parkeri* human infection was documented 3 years later.[11] Both cases were from the Tidewater region of Virginia, in the same region as Fort Eustis. New research has also revealed that multiple tick species within the *Amblyomma* genus can harbor *R parkeri*.[3,12] The many novel findings concerning *R parkeri* human infection indicate that much is still unknown about many human rickettsioses. Infection with *R parkeri* poses a significant threat to public health[2] because at least one-third of reported RMSF cases are believed to be caused by *R parkeri*.[3,4]

While *R parkeri* was newly identified as a pathogenic species, many other rickettsiae have emerged as possible pathogens, the most notable of which is *R amblyommii*. There have been tick bite rashes and probable RMSF cases associated with *R amblyommii*, though none have been confirmed.[13,14] *R amblyommii* has been found in large percentages of *Amblyomma americanum* ticks, commonly known as lone star ticks, and is believed to be the most common rickettsia infecting *A americanum* ticks.[13,15-17] *R amblyommii* and *Borrelia lonestari* have been suspected at one time to play a role in southern tick-associated rash illness (STARI), however the true causative agent of STARI has yet to be confirmed.[18-20] *A americanum* ticks are notoriously aggressive, nonspecific feeders whose geographic range covers a large portion of the continental United States.[21-23] A confirmation that *R amblyommii* is a human pathogen would be of great interest and concern.

Other tick-borne obligate intracellular bacteria pathogenic to humans are *E chaffeensis* and *E ewingii*, members of the order Rickettsiales, and agents of human monocytotropic ehrlichiosis (HME) and ewingii ehrlichiosis, respectively.[21] Human monocytotropic ehrlichiosis is a mild-to-fatal febrile illness with a case fatality rate of 2.7%.[24] A majority of HME patients require hospitalization; in one HME study, 85% of patients were hospitalized and many had serious complications. Older patients were more likely to develop complications and have longer hospitalizations.[25] *Ehrlichia ewingii* is known to cause a mild febrile illness in humans and may account for as much as 7% of all human ehrlichiosis cases in the United States.[26] *A americanum* is the main vector of *E chaffeensis* and *E ewingii*, while whitetail deer (*Odocoileus virginianus*) are the preferred vertebrate hosts of *A americanum*.[21] Vertebrate hosts infected with ehrlichiae are bacteremic for prolonged periods,[27] which increases the chance for transmission to a tick host. Human monocytotropic ehrlichiosis has been reported in 47 states, with the highest reported average annual incidence rates in Arkansas, North Carolina, Missouri, and Oklahoma. Additionally, two-thirds of HME cases occur between May and July.[24]

Fort Eustis is an approximately 3,197 hectare military installation located in the Tidewater region of coastal Virginia. Over 2,100 hectares of this property are in natural areas including pine-mixed hardwood forests, wetlands, and early successional habitat. These natural areas provide abundant opportunities for military training and recreational activities like golfing, camping, hiking, and hunting. These types of activities often center around the warmer months when many tick species are at their most active. A large component of the overall force health protection plan on Fort Eustis involves familiarity with natural hazards such as vector-borne diseases, which may be transmitted to personnel by the bite of an infected tick. Because numerous tick-borne rickettsiae like *R parkeri*, the etiologic agent of Tidewater spotted fever, are emerging as pathogenic bacteria, evaluation of ticks in the Fort Eustis area of Virginia was undertaken to determine the risk of tick-borne disease to residents and visitors. A large-scale surveillance effort was begun in October of 2007 to assess the tick fauna of designated portions of the property. A concise but limited portion of this effort is presented here.

## Materials and Methods

Specimens. Questing ticks were collected from 5 preselected locations by dragging a one meter square cloth for approximately 100 meters at each site once per month from May through August 2009. Site selection was based on suitable tick habitat, and individual sites

were divided between areas of high human use such as golf course edges and walking trails, and low-human use such as gated natural areas. Additionally, the sites were not treated with any type of pesticide prior to or during this study.

Nucleic acid purification. Adult and nymph ticks were identified and individually placed in 300 µL of Tissue Lysis Buffer (Qiagen, Valencia, CA). Larvae were similarly handled with the exception that 15 larvae were placed in each 300 µL of lysis buffer. Ticks were bisected with a sterile knife and incubated with the addition of proteinase K prior to nucleic acid purification according to kit directions with the DNeasy Blood & Tissue Kit (Qiagen). Purified nucleic acids were eluted with 100 µL of elution buffer. The bisected ticks, remaining lysate, and purified nucleic acids were stored at -80°C for future analysis.

Polymerase chain reaction (PCR) and quantitative real-time PCR (qPCR) assays. Purified nucleic acid preparations from individual (adults and nymphs) and pooled (larvae; n=15) *A americanum* ticks were analyzed for *R amblyommii* by the Rambl qPCR assay as previously described.[16] In addition, the *A americanum* samples were screened for *Ehrlichia* species in a 20 µL real-time multiplex reaction designed to amplify and differentiate a segment of the heat shock protein operon *groEL* of *E chaffeensis* and *E ewingii*[28] using the LightCycler FastStart DNA Master HybProbe kit (Roche) and 2 µL of sample. To be determined as positive, the sample melting peak was compared with a known standard and only samples that had an equivalent melting temperature were considered positive. Positive *E ewingii* samples were confirmed to species in a 25 µL conventional PCR reaction targeting the p28 gene[29] using the PuReTaq Ready-To-Go PCR Beads (GE Healthcare Biosciences, Piscataway, NJ) and 2 µL of sample. Samples positive for *E chaffeensis* were confirmed in a 20 µL qPCR reaction targeting the 16s rRNA sequence[30] using the LightCycler TaqMan Master kit (Roche) and 5 µL of sample. *Borrelia lonestari* infection was determined by screening with a SYBR Green I assay that amplified and detected a portion of the *glpQ* gene.[31] Real-time PCR with a melting curve was performed in a 20 µL reaction using LightCycler SYBR Green I master mix (Roche) and 5 µL of sample. Samples that produced a melting peak and equivalent Tm to the known standard were further analyzed with a conventional PCR that amplified a portion of the flagellen gene of *B lonestari*.[32]

Individual *D variabilis, A maculatum*, and pooled or individual *A americanum* nucleic acid preparations were screened for rickettsiae by the genus-specific Rick17b qPCR assay as previously described.[33] The screen positive *A maculatum* nucleic acid preparation was assessed by the species-specific Rpark and Rande qPCR assays for *R parkeri* and *Candidatus* Rickettsia andeanae, as previously described.[33] The single adult *I scapularis* (black-legged tick) was tested for *Borrelia* and *Anaplasma* with a real-time multiplex[34] using the LightCycler TaqMan Master Kit (Roche) in a 20 µL reaction with 5 µL of sample. Conventional PCR was performed on a MJ Research PTC 200 Thermal Cycler (Bio-Rad Laboratories, Hercules, CA), and real-time PCR reactions were performed on the LightCycler 2.0 instrument (Roche).

Standard PCR for sequencing. Standard and nested PCR assays were used to amplify outer membrane protein B (*ompB*) and A (*ompA*), and the surface cell antigen 4 (*sca4*) genes of *Rickettsia*.[34] The master mix was composed of Platinum PCR SuperMix High Fidelity (Invitrogen), 0.3 µM of primers, and one µL of template. All nested PCR were followed by gel electrophoresis run on a 1.5% agarose gel at 150 volts for 30 minutes.

Purifying PCR products. Nested PCR products were purified using either QIAquick PCR Purification Kit or DNA Gel Extraction Kit (Qiagen) when multiproducts were produced, 20 µL of buffer was used to elute the final DNA product.

Multilocus sequence typing was performed as previously described.[35] Briefly, purified PCR products were sequenced for both strands by using the Big-Dye terminator reagent (Applied Biosystems; Foster City, CA). Cycling temperatures were 25 cycles at 96°C for 10 seconds, 50°C for 5 seconds, and 60°C for 4 minutes. Sequencing reactions were cleaned up by using gel cartridges and run on a 3130 automated sequencing analyzer (Applied Biosystems). To obtain the final sequence data, Chromas software (Technelysium; Queensland, Australia) and Vector NTI software (Invitrogen; Fredrick, MD) were used.

## Results

Ticks collected. Eight hundred sixty-one ticks (0.4 per square meter) were collected by dragging a one meter square cloth for 100 meters at each of the sample sites on each date for a total of approximately 2,000 meters. Three hundred forty *A americanum*, 33 *D variabilis*, and 2 *A maculatum* were assessed for evidence of rickettsiae, *B lonestari, E ewingii*, and *E chaffeensis*. One *I scapularis* was assessed for *Borrelia* and *Anaplasma* species. Four hundred eighty-two *A americanum* larvae and 3 nymphs collected from 3 sites were not included in this study. All 4 tick species collected are considered man-biting pests and vectors of disease.

Table 1. *Amblyomma americanum* ticks collected by drag sampling at Joint Base Langley-Eustis, Fort Eustis, Virginia, May-August 2009.

| Life Stage | Number Collected | Number Tested (N) | *Borrelia lonestari* Number Positive (%N) | *Ehrlichia chaffeensis* Number Positive (%N) | *E ewingii* Number Positive (%N) | *Rickettsia amblyommii* Number Positive (%N) |
|---|---|---|---|---|---|---|
| Adult | 81 | 81 | 4 (5%) | 1 (1%) | 2 (2%) | 34 (42%) |
| Nymph | 37 | 34 | 0 (0) | 0 (0) | 2 (6%) | 16 (47%) |
| Larva | 707 | 225 (15 pools) | 0 (0) | 0 (0) | 0 (0) | 15 (7%) MIR* |

*Minimum infection rate, larvae tested in pools of 15 individuals.

*Amblyomma americanum* ticks assessed for *Rickettsia*, *Borrelia* and *Ehrlichia*: Purified nucleic acid preparations from the 340 (81 single adults, 34 single nymphs, and 15 pools of larvae) *A americanum* ticks selected for analysis were subject to qPCR testing for *R amblyommii*, *B lonestari*, *E ewingii*, and *E chaffeensis* (Table 1). *Borrelia lonestari* was detected in 2 male and 2 female *A americanum* adults for an infection rate of 5% of the adults tested. *Ehrlichia chaffeensis* was detected in one (1%) of the adult ticks tested, and *E ewingii* was detected in 2 (2%) adult and 2 (6%) of the nymph samples. Neither of these organisms were detected in the pools of larval ticks. *Rickettsia amblyommii* was detected in a minimum of 65 samples, and no further analysis was performed.

*Dermacentor variabilis, A americanum* and *A maculatum* ticks analyzed for *Rickettsia* species. Thirty three adult *D variabilis,* 2 female *A maculatum* and 340 adult and immature *A americanum* ticks were tested for rickettsiae (Tables 1, 2). All *D variabilis* ticks were negative, however, *R amblyommii* was detected in a minimum of 63 *A americanum* ticks. *Rickettsia* species was detected in one of the 2 female *A maculatum* with the Rick17b and Rpark qPCR assays (Tables 1 and 2). Subsequently, the *Rickettsia* species positive DNA sample preparation from the *R parkeri* positive *A maculatum* adult tick was analyzed by multilocus sequence typing using *ompA*, *ompB*, and *sca4* genes. Two fragments of *ompA* (648 and 856 bp) and *ompB* (806 and 584 bp), and one fragment of *sca4* (812bp) were 100% identical to *R parkeri* Maculatum 20 (GenBank #AF 123717). The *Candidatus* Rickettsia andeanae qPCR assay (Rande) was negative for the *R parkeri* positive sample.

The ubiquitous occurrence of *A americanum* collected at Fort Eustis along with the aggressive man-biting character of this tick species indicates that the potential risk of rickettsial and ehrlichial human infections could be high in the summer months in this area. Another possible public health threat is STARI, which has been documented following an *A americanum* tick bite.[35] Even though *R amblyommii* and *B lonestari* have been suggested as possible agents of STARI, the true etiologic agent of this disease has yet to be identified.[18,20] An additional potential health concern associated with *A americanum* is the recent discovery of *R parkeri* in Lone Star ticks collected in Tennessee and Georgia.[37] In this study, we did not detect *R parkeri* in any of the *A americanum* ticks tested.

*Dermacentor variabilis* ticks are known to carry *R rickettsii*, the causative agent of RMSF, and *R montanensis*, a rickettsia of unknown human pathogenicity.[38] No rickettsial agent was identified in the small number of *D variabilis* ticks assessed. This is not surprising since *R rickettsii* are rarely found in *D variabilis*, even in areas highly endemic for RMSF,[39] and *R montanensis* is usually detected in only 5%-19% of *D variabilis* evaluated.[9,17,38]

One of the 2 adult *A maculatum* ticks collected in this study was found to harbor *R parkeri*. A low number of Gulf Coast ticks identified in Fort Eustis or the Tidewater region is not surprising since its presence in this area and throughout Virginia has only been sporadically encountered.[40,41] With that said, it is interesting that 2 of the first reported *R parkeri* rickettsiosis cases occurred in the Tidewater area of Virginia.[10-11] *R parkeri* was initially isolated from *A maculatum* ticks in 1937[42] and has recently been found in multiple *Amblyomma* species such as *Amblyomma triste*,[12] *A americanum*,[37,43] *Amblyomma nodosum*,[44] and experimentally in *Amblyomma*

Table 2. Ticks collected by drag sampling at Joint Base Langley-Eustis, Fort Eustis, Virginia, May-August 2009.

| Tick Species | Life Stage | Number Collected | Number Tested (N) | *Borrelia/Anaplasma* Number Positive (%N) | *Rickettsia* Species Number Positive (%N) | *Rickettsia parkeri* Number Positive (%N) |
|---|---|---|---|---|---|---|
| *Amblyomma maculatum* | Adult | 2 | 2 | Not tested | 1 (50%) | 1 (50%) |
| *Dermacentor variabilis* | Adult | 33 | 33 | Not tested | 0 (0) | 0 (0) |
| *Ixodes scapularis* | Adult | 1 | 1 | 0 (0) | Not tested | Not tested |

*cajennense*.[45] The discovery of *R parkeri* infected ticks at Fort Eustis (in the Tidewater region of Virginia) combined with 2 Tidewater *R parkeri* human infections[10,11] from the same region implies that residents of and visitors to the Tidewater area may be at risk of *R parkeri* infections. In addition, *A maculatum*, endemic to the southern United States,[40,41,46] may be widening its geographic range, implying that the geographic range of *R parkeri* is expanding as well. If the endemic region of *A maculatum* and *R parkeri* are growing, healthcare providers should be made aware of possible *R parkeri* rickettsiosis in their areas, and that Tidewater spotted fever has been confused for RMSF.[4] The results of this study reveal the need to learn more about the distribution of this vector in the Tidewater region, the prevalence of *R parkeri* infection of the Gulf Coast tick, and the incidence of Tidewater spotted fever in this area.

The inherent sampling bias of the cloth drag method is well explained by Schulze et al.[47] However, in this instance it was employed as a surrogate to estimate rates at which a human may encounter ticks at Fort Eustis. Based on this assessment, the potential exists to encounter at least 4 ticks per 10 meters traveled on foot in natural, training, and recreational areas at Fort Eustis. Furthermore, pathogenic *R parkeri, E ewingii and E chaffeensis* which pose a risk to human health in the region were identified in 5% of the questing adult and nymph ticks collected from Fort Eustis. The predicted rate of encounter of an infected adult or nymph tick may be as high as 5 infected ticks per 100 meters traveled. Human rickettsial and ehrlichial diseases including RMSF and HME[1] are difficult to recognize and may be misdiagnosed due to their often cryptic symptoms. Since *R parkeri* has been recognized as a human pathogen only for the past few years, there is an even greater chance of misdiagnosis of *R parkeri* rickettsiosis. Indeed, one-third of supposed RMSF cases are believed to be misdiagnosed *R parkeri* cases.[4] Clinicians, therefore, should be aware of this condition. Moreover, studies are needed to determine the occurrence, distribution, and seasonality of *A maculatum* and *R parkeri* in the mid-Atlantic states of North Carolina, Virginia, and Maryland, which were previously not known to have long-established populations of *A maculatum*. Likewise, *E chaffeensis* and *E ewingii*, the discoveries of which occurred in 1986 and 1999, respectively, are also relatively unknown agents associated with the underreported disease HME and ewingii ehrlichiosis.[24,25] Location of the diseases and their arthropod vectors are essential in informing medical health care providers, preventive medicine personnel, and the general population as to the risk of tick-borne diseases.[48]

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# Honey Bee Swarms Aboard the USNS *Comfort*: Recommendations for Sting Prevention, Swarm Removal, and Medical Readiness on Military Ships

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ABSTRACT

The article provides observations of multiple honey bee (*Apis mellifera*) swarms aboard the USNS *Comfort* (TAH-20) during the Continuing Promise 2015 mission. A brief overview of swarming biology is given along with control/removal recommendations to reduce sting exposures. The observations suggest that preventive medicine personnel should provide adequate risk communications about the potential occurrence of bee swarms aboard military ships, and medical department personnel should be prepared for the possibility of treating of multiple sting exposures, especially in the Southern Command Area of Operations where the Africanized genotype of *A mellifera* is common.

Hymenoptera envenomization poses an environmental threat during military contingency operations and venom hypersensitivity can pose a serious health hazard.[1] *Army Regulation 40-501*[2] lists anaphylaxis to arthropod stings as a disqualifying medical condition. The US Army Medical Command issued a stinging insect policy providing additional assessment and management guidance of Soldiers with a possible allergy to stings.[3] The Navy and Marine Corps follow guidelines in the *Manual of the Medical Department*[4] which states that a current history of severe allergic reaction, anaphylaxis, or life threatening manifestations to environmental substances is a disqualifying condition for active duty service. Allergies that require allergy immunotherapy are also disqualifying unless a period of desensitization can be accomplished during a period of limited duty. However, there are medical or administrative waivers to gain entry into the US armed forces. In these cases, venom hypersensitivity must be clearly denoted on personnel medical documents, and medical/pharmacy departments are to ensure service members are equipped with epinephrine auto-injectors, especially during predeployment health screenings. Physicians can also issue service members with documented hypersensitivity to insect stings a medical warning tag per *Bureau of Medicine and Surgery Instruction 6150.35*.[5]

In austere field settings where active duty personnel work, allergic reactions to Hymenoptera stings can be especially challenging, particularly since a history of allergic reactions to stings is many times not known previous to exposure. In the United States, half of all fatal reactions reportedly occur with no history of previous sting reactions.[6] Onboard ships and in field locations, a Navy corpsman or an Army medic with a small supply of medicines and equipment may be the only healthcare providers available. The standard medical bag carried by Marines in field settings or stocked on small Navy ships includes an epinephrine auto-injector (eg, EpiPen). For Navy Corpsman who work directly with operational units, including but not limited to Marines, Seabees, or other special operations, medical records are reviewed prior to any deployment or exercise. This is done to get a brief medical overview of the personnel they are responsible for, and ensure that proper medication is on hand in case of anaphylactic emergencies. Following instructions provided in the US Navy *Manual of the Medical Department*,[4] specifically Article 21-3 12b, Navy corpsman will ensure that the service member who has an allergy to Hymenoptera stings has an epinephrine auto-injector issued to them and inspect to ensure the member possesses it before deployment. Individual commands may also write local instructions and policies specifying when it is mandatory for members to carry an EpiPen. This could also be a written directive from the member's healthcare provider issuing the prescription (*Manual of the Medical Department*[4] Article 21-4). Directions accompanying an EpiPen also state that the device should be carried with the patient.

Hymenoptera, the order of insects comprised of bees, hornets, wasps, and ants, tend to be more aggressive and apt to sting when there is greater sociality within a species.[7] Social or semisocial bees that live in colonies, especially near man-made structures, increase the risk of sting exposures for 2 primary reasons:

- Social bees are more sensitive to perceived threats in order to protect brood and food resources in the hive.
- Humans tend to prefer not to have them in close proximity and make efforts, often using counterproductive means, to rid the area of nesting or swarming bees.

During a 2010 deployment in support of Operation Enduring Freedom, a study was conducted to determine the prevalence of insect stings and venom hypersensitivity in military personnel operating in Afghanistan.[1,8] Three species most commonly encountered by military personnel included social species in the superfamilies Apoidea (bees) and Vespodiea (wasps): *Polistes wattii* Cameron, *Vespula germanica* (Fabricius), and *Vespa orientalis* Linnaeus. These species were frequently observed near man-made structures located on military installations.

Highly social honey bee (*Apis mellifera* L.) colonies swarm for a variety of reasons. These swarms usually occur when bees move from one location to another to search for a site to construct a new hive, which is a natural means of honey bee reproduction. Swarming is initiated when the queen bee leaves the original hive with the rest of the colony following her movements. Because the queen is not a strong flyer, she will rest often, making the remainder of the colony stop along the way to new nesting sites. The swarming season is typically a 4-6 week period and occurs in the late spring or early summer, but this may vary due to geographical location. Bees moving in the swarm tend to be less aggressive as there are no immatures (brood) to tend to or food to protect; however, because these bees are protecting the queen, any perceived threat may trigger an alarm pheromone resulting in bee stings to anything nearby. This may be especially important in the Southern Command Area of Operations (SOUTHCOM AOR) where the Africanized genotype of *A mellifera* is more prevalent. As of 2012, established populations of Africanized honey bees were found in every country in Central and South America except Chile.[9]

Africanized honey bees respond to food shortages by migrating and make small to large colonies that reproduce (swarm) often, ranging from 4-8 times a year.[10] It is unclear if Africanized honey bees were encountered during the Continuing Promise 2015 mission discussed in this article because they are morphologically indistinguishable (without morphometric calculations) from the European honey bee. However, one key difference is that the Africanized genotype tends to swarm more commonly than the European genotype due to frequent hive overcrowding.[9] Africanized honey bees are also aggressively protective of their young and respond quickly by viciously stinging a suspected intruder and may attack more than 5 feet from the nest. It has also been noted that strong equipment vibration can activate Africanized honey bees from a distance of greater than 100 feet.[11] There is detailed biological and behavioral information on bee swarming in the literature and in various extension publications[12,13]; thus, swarming behavior is not covered in great detail here.

The presence of bees or bee swarms may be an overlooked force health protection issue aboard ships while underway or in port. We report here the occurrence of at least 4 bee swarms and numerous honey bee reports aboard ship while deployed with the USNS *Comfort* (TAH-20) in support of the humanitarian mission Continuing Promise 2015, which was conducted throughout much of the SOUTHCOM AOR. For this deployment, an entomologist was onboard to provide guidance on how best to manage the presence of bees to prevent sting exposures; however, supplies were not available to remove bees if required. Personnel on less well-informed ships may sustain unnecessary stings due to inappropriate removal tactics and lack of knowledge about bee behaviors. This may be especially important on ships without adequate medical services to respond to severe sting reactions.

Upon conducting a literature search using Google online search terms "honey bee," "swarms," "Navy," "military," "ships," we could not find any previous reports of bee swarming aboard military ships. While bee swarming has apparently not been previously documented, it is not a new phenomenon. Along with our observations aboard USNS *Comfort*, we have received other anecdotal reports of bee swarms aboard various seafaring vessels including previous missions aboard the *Comfort*. Bee swarms were observed on USS *Iwo Jima* (LHD-7) on a forklift as shown in Figure 1 during Continuing Promise 2010 (R. Flores, written communication), and on USNS *Comfort* during Continuing Promise 2011 as observed by author J. D. Stancil. In 2014, a large bee swarm was observed on a crash and salvage crane aboard the USS *Peleliu* (LHA-5) while pierside in the Republic of Philippines (C. Guckeyson, written communication) (Figure 2). Navy Environmental and Preventive Medicine Unit-6 (NEPMU-6) preventive medicine personnel responded to swarms aboard USS *Preble*


Figure 1. Bee swarm (red arrow) on a forklift aboard the USS *Iwo Jima* (LHD-7). Image courtesy of HM1 Robert Flores.

(DDG-88) and USS *Port Royal* (CG-73) while the ships were in port in Pearl Harbor, Hawaii, in 2014 (E. Gerardo, written communication). To the best of our knowledge, however, this article is the first effort to formally document this phenomenon and develop hypotheses as to why it occurs aboard ships. In this note, we document our observations, provide recommendations to prevent sting exposures, and offer solutions to the safe removal of bees during shipboard operations. We hope this leads to a better understanding of bee swarming behavior and the ability of shipboard personnel to prepare for this potential health risk.

## Honey Bee Observations

During the Continuing Promise 2015 mission, bee swarms on the USNS *Comfort* were first noted while at anchor near the coast of Guatemala on April 23, 2015. Within 2 days after dropping anchor approximately 8 miles off the coast of the port city Puerto Barrios, a bee swarm was reported near the ship's bridge. The swarm was encompassing a utility box covering a thermometer located on the bridge (Figure 3). The bees were not aggressive, although at least one sting was reported. Many of the bees were vibrating their wings, likely in an attempt to regulate the ambient temperature for the queen and maneuvered around the box to avoid being in direct sunlight. Rapid wing vibrations may also have been a result of worker bees releasing pheromones using their wings to disseminate chemicals to orient forager bees back to the colony. The total number of bees slowly declined until all bees had left the area within 48 hours of initial reports. There were also numerous individual bees reported in many areas of the ship throughout the time it was anchored at this location. These may have been scout bees from the swarm looking for a suitable place to nest.

At least 3 bee swarms were again noted while pierside in Acajutla, El Salvador, starting on June 17. Swarms were reported within the first day of arrival. Swarms were located on an antenna located towards the bow (forward) (Figure 4) on June 17, an air conditioning unit towards the stern of the ship (aft) (Figure 5) on June 18, and the base of an aft antenna (Figure 6) on June 19. The bee swarm located on the forward antennae departed within 24 hours of first being observed, and it is not clear if this group moved to different locations noted for the other 2 sightings. The bee swarm located on the aft air conditioning unit remained until June 21, but the number of bees appeared to decline daily from initial reports. In

Figure 2. Bee swarm (red box) on crash and salvage crane aboard the USS *Peleliu* (LHA-5). Photo courtesy of HMC Chris Guckeyson.


Figure 3. Bee swarm on thermometer box aboard USNS *Comfort* (TAH-20) off the coast of Guatemala. Photo provided by LCDR J. Dunford.

Figure 4. Bee swarm (red box) on antenna aboard USNS *Comfort* (TAH-20) in port in Acajutla, El Salvador. Photo courtesy of LCDR J. Dunford.

Figure 5. Bee swarm on air conditioning unit aboard USNS *Comfort* (TAH-20) in port in Acajutla, El Salvador. Photo courtesy of LCDR J. Dunford.

Figure 6. Bee swarm on base of aft antenna aboard USNS *Comfort* (TAH-20) in port in Acajutla, El Salvador. Photo courtesy of HM1 L. Peet.

addition, this location on the upper portion of the ship had numerous dead bees located near the air conditioning units. The bee swarm located on the aft antenna on June 18 had departed by June 21. Although no swarms were observed, numerous individual bee sightings and complaints were also made aboard ship at a port stop in Colón, Panama, between June 30 and July 5.

## Medical Reporting of Hymenoptera Stings

We mined medical records in the ship's log for any reported Hymenoptera stings or suspected allergic reactions to bee stings. During the mission, 7 patients reported to sick bay for arthropod-related stings or bites. Three were classified as general bug bites, two were spider bites, and two were attributed to bee stings. One of the bee stings was reported on April 28 by a civil mariner, and an active duty service member reported

the other bee sting June 18. The bee stings were reported during mission stops (Guatemala and El Salvador) in which bee swarms were observed aboard ship. No serious reactions were reported for any of the arthropod-related stings or bites.

## Recommendations

Most bee swarms, especially aboard a ship where no food sources (eg, flowers) are readily available in close proximity, will leave on their own in a few hours or days. Accordingly, a simple rule of thumb is to not panic, and maintain a safe distance from the swarm. Many sting exposures are due to unnecessary aggravation of the swarm, such as throwing objects or spraying various substances in an attempt to get them to move on. Bees are typically docile during swarming unless provoked by an inappropriate attempt to rid the area of the swarm. A first reaction might be to use insecticide applications, but this is not recommended. Insecticide applications may provoke the bees, and is completely unnecessary unless the bee swarm appears to be building cells for nesting or where operational commitments dictate immediate bee removal. If a swarm cannot be allowed to leave naturally, the first option is to consider hiring a professional bee removal service to remove and safely relocate the swarm. However, this option is typically not possible during shipboard contingency missions unless a local vendor is available for hire while in port. We recommend contacting the US Embassy in the port country to determine if a suitable vendor is available and has been vetted for pest control services. Because of the value of honey bees in crop production, bee removal is often done for free or for a minimal charge. This may be a viable option while in port, especially in the United States, for long periods of time. Local farmers and national beekeepers associations may also be contacted for bee removal services.

During contingency missions or in foreign ports, especially those in the SOUTHCOM AOR where the Africanized honey bee genotype is more prevalent, we recommend reporting bee swarms immediately to preventive medicine personnel. They should then work with the appropriate shipboard personnel to set up a safe perimeter around the bee swarm until it departs. Based on author J. C. Dunford's observations of bee swarm behavior aboard the USNS *Comfort*, a safe perimeter is at least 25 feet from the swarm as illustrated in Figure 7. It should be noted that Africanized honey bees can perceive threats 50 feet or more away from their nest; however, swarms tend to be more docile. The perimeter should be clearly marked with 'Do Not Enter' signs along with information about the presence of a bee swarm. This area should then be checked periodically by preventive medicine or other informed personnel until the swarm has moved on. During Continuing Promise 2015, the ship's Master at Arms played an important role in locating bee swarms, reporting, and directing his personnel to follow the recommendations of the Directorate for Public Health. Keeping personnel a safe distance away from swarms not only prevents intentional exposure (eg, during inadequate attempts to remove the bees), but also accidental exposure, as we found that in many cases individuals transiting the decks were not aware of the presence of the bees. Operating equipment that creates strong vibrations near a bee swarm is also not advisable as this may trigger the bees to react to perceived danger.

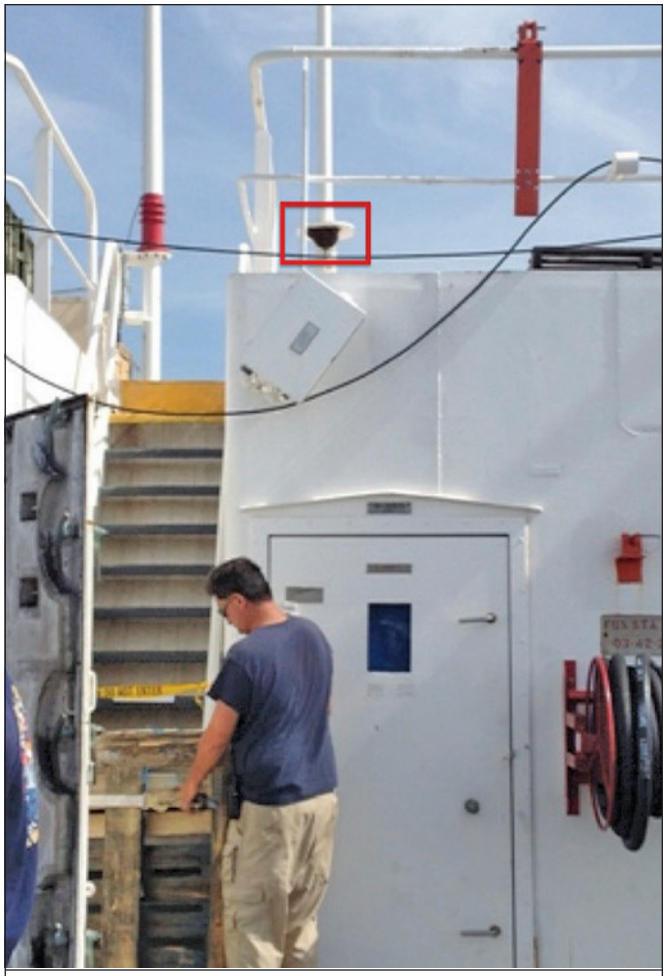

Figure 7. Civil mariner blocking area with bee swarm (red box) on base of antenna (also shown in Figure 4) aboard USNS *Comfort* (TAH-20) in port in Acajutla, El Salvador. Photo courtesy of LCDR J. Dunford.

Although the swarm is likely to depart its temporary resting site within a few hours or days, the swarm's location may hinder operational duties or may be located in a space frequented by personnel that require access to it. In addition, if scout bees leaving the swarm are unable

to find a suitable nesting site, the swarm may start construction of their combs on a structure on which they have clustered, even though this would not be optimal for the colony on a ship. For the bees, a suitable nesting location may be an area well protected from the elements, receive a certain amount of warmth from the sun, and be 15 liters in volume. When these circumstances exist, there may be no other option but to destroy the swarm to prevent sting exposures. We recommend that preventive medicine units consider procuring a beekeeping suit for shipboard missions, especially in the SOUTHCOM AOR, as part of their entomological equipment build, as it is the only effective means to protect personnel applying insecticides or attempting to relocate a swarm, especially Africanized honey bee swarms. If feasible, relocation of the colony is possible by following techniques often used by beekeepers but should be done so only with proper personal protective equipment (ie, full beekeeping suit; or fire suit, keeping in mind potential heat stress issues) ensuring all exposed skin is covered and gaps between the head gear, suit, gloves, and boots are sealed (or tucked in) using rubber bands, Velcro, or duct tape.

Beekeepers may use traps baited with Nasonov pheromone to attract swarming bees. This naturally occurring pheromone consists of several terpenoids and is used to orient foraging bees back to the colony. Other capture methods include using a bee vacuum or equivalent with enough suction to collect all of the bees in a container to keep them from escaping after being captured. A suitable box with a small opening called a nuc (similar to empty beehive) can also be used. If a bee swarm is encountered, a white sheet can be placed under the swarm location with a nuc box placed on the middle of the sheet. The swarm can be sprayed with a sugar solution and then shaken or scrapped off the resting surface into the nuc. If the queen does enter the nuc, most of the remaining colony will follow soon thereafter. This capture method can only be performed during the day and should be done wearing personal protective equipment described earlier.

As a last option, insecticides approved for bee control can be used to destroy the swarming colony. Given the recent decline in bee populations in many parts of the world, we do not recommend destroying honey bee colonies; however, mission objectives may require this action. Department of Defense approved pesticides should be used strictly following label instructions and used only by pesticide applicator certified personnel (if required following insecticide label). A current list of approved pesticides can be found at the Armed Forces Pest Management Board web site (http://www.acq.osd.mil/eie/afpmb/). All personnel, including onlookers, should be adequately protected or clear of the area to prevent bee sting exposures during insecticide applications. Insecticides should be applied directly to the swarm and dead bees should be removed from the area and discarded. As an alternative, spraying soapy water (one cup of liquid dishwashing detergent per gallon of water) in a high volume spray may also be used and applied using maximum personnel protective gear such as a beekeeping suit. Preventive medicine personnel from NEPMU-6 responding to a bee swarm aboard the USS *Port Royal* used this technique to successfully neutralize over 1,000 bees (E. Gerardo, written communication). Other surfactants, such as aqueous film firefighting foams will also work. Specific surfactant examples include Palmolive dishwashing liquid, 9-55 fire control chemical, Sivex Rfoam concentrate, and FC-600 aqueous film-foam.[14]

In the unfortunate case that bees are attacking, personnel must exit the area as quickly as possible. Africanized honey bees will continue to defend their nest for a distance of a ¼ mile or more; thus, it is important to protect the head, eyes, nose, and mouth with hands, arms, or clothing. Enter a sheltered area to get away from the majority of the swarm and seek medical attention if stung. The lethal dose of bee venom for a human is approximately 10 stings per pound of body weight.[10] If one or a few stings are noted, practical first aid measures such as stinger removal by scraping using a fingernail, dull knife, or credit card are warranted. The patient should then be monitored for any signs of anaphylaxis. Betten et al[15] consider a massive attack to be 50 stings or more. When the number of stings is less than 50, and the victim is not hypersensitive to the venom and properly treated, conservative, supportive care is appropriate.[9] It should be noted that about half of the people who have anaphylactic reactions to bees stings do not have a history of bee allergies, and victims should be specifically questioned about warning symptoms such as development of hives, breathing difficulties, or dizziness which are not always recognized immediately due to the distraction of the painful stings.

Although the toxicity of Africanized honey bees is similar to the European honey bee, multiple stings in a short period of time can cause severe allergic reactions. Massive envenomization is rare, and treatment of severe allergic reactions includes management of shock, hypoxia, and other effects on the organs. Personnel with no known bee allergies are still at risk for systemic anaphylaxis as discussed above, which may be exacerbated by multiple bee stings[16] which is often seen when attacked by Africanized honey bees. Although rare, strokes have also been reported following multiple bee stings.[17] The

cosmopolitan distribution and prevalence of *A mellifera* (and Hymenoptera in general) increases the likelihood that adults have had previous sting exposures to various genotypes of this species. Based on studies evaluating the cross-reactivity of insect venoms, it can be assumed that closely related species would likely pose a greater threat to an individual with previous sting exposures during one's lifetime[18,19]; thus, insect venom hypersensitivity in service members should be closely and continuously monitored. Predeployment questionnaires during overseas health screenings should clearly denote known history of Hymenoptera venom sensitivity and treatment should be available. Medical departments should also ensure readiness for bee stings including protocols to treat massive envenomization or patients with hypersensitivity to Hymenoptera venom. Upon embarkation, the USNS *Comfort* had 8 EpiPen injectors available for use, in addition to aqueous epinephrine stocked in the ship's pharmacy. While the *Comfort* has a well-supplied pharmacy, there are no formal instructions on how other vessels should be stocked. Predeployment force health protection briefs should include awareness of stinging insects and emphasize avoidance measures to limit contact with potentially aggressive Africanized honey bee colonies.

## Comment

During Continuing Promise 2015, bee encounters were the most numerous arthropod-related complaints from crew aboard ship. Bees apparently use ships as an intermediate stop before finding a suitable location to build a new hive, and we speculate that bee swarms may be attracted to artificial cues emitted by antennas and other mechanical equipment aboard ship. There were several areas on the ship where vibrations, heat, visual, or olfactory emissions may have attracted swarming colonies. Air conditioning units on the ship vibrate and radio antennas may also transmit vibrations via subtle wavelengths; bee swarms were noted at both such locations during Continuing Promise 2015. Gilbert et al[20] noted that vibration signals may influence nest-site selection in honey bees by enhancing scouting and recruitment. Vibration signal activity and recruitment or waggle dances are known to play a role in colony liftoff preparations and swarm movement within colonies.[21] A primary function of these signals during house-hunting may be to generate a level of activity in workers that coordinates responses that stimulate departure and movement to new nesting locations. It is unclear if subtle vibrations transmitted by equipment on the ship played a role in attracting or interfering with the colony's ability to find suitable nesting locations; thus, further investigation into bee swarming on ships and where colonies are observed resting is needed. Alternatively, a ship may simply be a large object on which to to rest along the way to finding suitable nesting sites.

Adequate risk communication on bee swarming is important to reduce fear of bee sting exposures and prevent unnecessary attempts to remove bees. Honey bee (or Hymenoptera in general) biology and avoidance countermeasures should be passed to ship's crew before and periodically during contingency missions. Previous to disseminating this information during Continuing Promise 2015, the presence of the bees caused undue alarm as well as failed attempts to rid the area of bees, resulting in some reported bee stings where treatment was not sought. In some cases, the bee swarms went unnoticed (increasing the risk for accidental exposure) by personnel transiting the affected areas. Using the name Africanized honey bee and not "killer bee" is preferable during force health protection briefings to reduce the normal fear associated with the latter, often misleading description of honey bees in the SOUTHCOM AOR.

Based on what is known about bee swarming biology, we do not recommend attempting to kill bees using insecticides for a variety of reasons, including safety of ship's personnel as well as recent decline in bee populations worldwide. In most instances, bee swarms will move on within hours or a couple of days after arriving aboard a ship. It should be noted that honey bees, including Africanized varieties, are beneficial insects for their pollination services. Honey bees have also been trained to detect explosives and diseases such as cancer.[22,23] The frequency and temporal trends of encountering large bee swarms during shipboard operations is not well documented, and lack of preventive countermeasures in advance may leave few options for bee removal and adequate risk communications to prevent sting exposures. We hope that this information provides preventive medicine/medical departments several options to prepare for such phenomenon during predeployment supply acquisitions, and provides a template to issue risk communications in the plan of the day or during other force health protection briefs for widest dissemination. Although swarming bees can be alarming to ship's crew, sting exposures can be minimized with proper preparation and adequate avoidance measures. Our overarching goal is to improve risk communication on bee swarms and bee stings, and we encourage additional reporting of bee swarms aboard ships during future missions.

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# Mortality From Fungal Diseases in the US Air Force From 1970 to 2013

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## Abstract

We review a unique set of documents, death certificates, catalogued in the US Air Force Mortality Registry, which tracks deaths for current and retired Air Force service members. We screened the records for all deaths caused by fungal diseases between 1970 and 2013. There were 216 deaths caused by a variety of diseases such as aspergillosis, blastomycosis, candidiasis, coccidioidomycosis, cryptococcosis, histoplasmosis, mucormycosis, pneumocystosis, sporotrichosis, and zygomycosis. The single most common identified cause of death was opportunistic candidiasis. Of the total 216 deaths, only 7 were active duty or active reserve personnel.

Fungal diseases rarely cause death in healthy young people. Both obligate parasitic fungi and opportunistic pathogens cause these diseases. Some military personnel are infected in their work environment with fungal pathogens such as the agents of histoplasmosis and coccidioidomycosis. Certain fungal diseases pose an increased threat to military personnel and retirees because of the frequency of serious wounds, amputations, and organ transplants compared to the overall civilian population. The Department of Veterans Affairs treats veterans and retirees for wounds and diseases acquired while in service.

There are ample reviews of historic disease trends in the US military; however, little comprehensive work has focused on all fungal deaths in the US Air Force (USAF).[1] Previous reviews of zoonotic disease morbidity in the USAF did not consider fungal disease zoonotic,[2] even if some derive from animal exposure. The US Air Force School of Aerospace Medicine maintains the Air Force Mortality Registry (AFMR). The AFMR is a unique resource that creates a database of all mortality data from death certificates, autopsy reports, etc, for active, reserve, and retired USAF service members to track trends and patterns that are more precise than Department of Defense casualty data. The AFMR tracks all causes of death including those from occupational and fungal diseases. We review those deaths in the context of historical disease significance and modern trends.

## Materials and Methods

We queried 442,856 AFMR death records for all deaths after December 31, 1969, to December 31, 2012. The AFMR uses the *International Classification of Diseases-10th Revision* (ICD-10) codes to track causes of death. Death records were accessed when the ICD-10 code matched any of the following (or their subsections): aspergillosis, blastomycosis, candidiasis, coccidioidomycosis, cryptococcosis, histoplasmosis, mucormycosis, pneumocystosis, sporotrichosis, zygomycosis, and unspecified mycosis. We analyzed each record. We further examined the death certificates which cite unspecified mycosis in an attempt to verify the fungal cause of death. We also examined death certificates in detail to verify place of death and other causes of death, if any. The death records included in this study were those of all individuals reported to have had a fungal disease as underlying cause of death. We used SAS 9.3 (SAS Institute Inc, Cary, NC) software for our analysis.

## Results and Comment

Overall, there were 216 deaths from fungal diseases from 1970-2012, summarized in the Table. There are limits to the data in the AFMR. Death records prior to the mid-1980s are sparsely represented and not all recent deaths have been documented, so records after 2010 could be underrepresented.

Pathogenic and parasitic fungi are ubiquitous but rarely cause death in the developed world. They are often associated with travel, the elderly, or a compromised immune system. Fatalities from fungal diseases are most often seen in the elderly as secondary infections, following organ transplants or chronic disease. Some fungi are legitimate parasites while others are only opportunistic environmental pathogens. We address each fungal pathogen alphabetically instead of following phylogenetic order.

**Aspergillosis:** *Aspergillus* spp are truly ubiquitous fungi with airborne conidia throughout the world.[3] They produce aflatoxins, but we did not consider any deaths related to these toxins. *Aspergillus* spp are saprophytic fungi, but aspergillosis threatens patients who

are immunocompromised, and fatal cases of aspergillosis increased after the introduction of corticosteroids and immunosuppressant drugs.[4] Aspergillosis is currently the leading cause of fungal deaths in the United States.[3] It was the second most common cause of death in the study, with 36 deaths. The first death recorded in the AFMR was in 1989. Sixty-one percent (n=22) of aspergillosis deaths were recorded from 2000 to 2012, with 1 and 13 deaths recorded for the 1980s and 1990s, respectively. We have not found a record of a female death thus far. The deceased were retirees, 55 years and older, the majority of whom died of pulmonary infections.

Characteristics of individuals with fungal cause of death listed for the period 1970-2012 (N=216) in the US Air Force Mortality Registry.

| Variable | n | %N |
|---|---|---|
| Gender | | |
| Male | 211 | 97.69 |
| Female | 4 | 1.85 |
| Unknown | 1 | 0.46 |
| Age Group | | |
| 20-44 years | 18 | 8.33 |
| 45-54 years | 16 | 7.41 |
| 55-69 years | 50 | 23.15 |
| 65 years and older | 135 | 61.11 |
| Race | | |
| White | 167 | 77.31 |
| Black | 32 | 14.81 |
| Hispanic | 4 | 1.85 |
| Unknown | 13 | 6.02 |
| Underlying Cause of Death | | |
| Aspergillosis | 36 | 16.67 |
| Blastomycosis | 4 | 1.85 |
| Candida | 43 | 19.91 |
| Coccidioidomycosis | 32 | 14.81 |
| Cryptococcosis | 12 | 5.56 |
| Histoplasmosis | 12 | 5.56 |
| Mucormycosis/Zygomycosis | 7 | 3.24 |
| Pneumocystosis | 25 | 11.57 |
| Sporotrichosis | 2 | 0.93 |
| Unspecified mycosis | 43 | 19.91 |
| Duty Status | | |
| Active Duty/Active Reserve | 8 | 3.70 |
| Retiree | 208 | 96.29 |

Blastomycosis: *Blastomyces dermatitidis* causes this relatively rare fungal disease. Most cases in the United States were acquired in the eastern half of the country, with a rate of approximately 2 per 100,000 people.[5]

This disease is relatively rare, with a low overall rate of mortality, but in some studies the death rate can exceed 12% in individuals over 65 years of age.[5] In the USAF, there were 4 deaths, all of which were retired males with either disseminated or unspecified infection sites. Four deaths were recorded from 1999 to 2003, with one death per year, 2001 being an exception. There were no records of death from blastomycosis after 2003.

Candidiasis: Numerous *Candida* spp cause candidiasis, with *Candida albicans* being the most frequently reported.[6] Disseminated or invasive candidiasis is one of the most prominent fungal causes of mortality in the United States. While invasive candidiasis is rare in people without risk factors, it is the fourth most common cause of hospital-acquired bloodstream infections in the United States.[6] Patients often acquire candidiasis following a traumatic injury or organ transplantation, or after suppression of the immune system due to age and/or other illness. Almost all of the 43 deaths (91%) recorded in the AFMR were men over the age of 60. While we are unable to know if they were suffering from underlying conditions, that is probable. A majority of cases (n=20 (46%)) were recorded from 2000-2012, preceded by 16 (37%) in the 1990s.

Coccidioidomycosis: This disease is generally restricted to the western United States, where the causative agent *Coccidiodes immitis* is endemic. It is an occupational hazard for military personnel training where soil is disrupted, such as on bombing ranges.[7] Coccidioidomycosis contributed the third highest number of fungal deaths during our study period. Coccidioidomycosis was one of the most significant fungal causes of death for USAF retirees, with 32 deaths. There is no way of knowing if they acquired the infections while on active duty. It also caused 3 deaths of active duty airmen, with a death in 1970, 1972, and 1992. Of these, approximately 75% died in western states, and the other cases could have been acquired there and reported at the site of death. Almost half of the deaths (n=15 (46%)), were recorded in the 1990s.

Cryptococcosis: Several *Cryptococcus spp* cause cryptococcosis. *Cryptococcus gattii* causes disease and is most common in immunocompetent people.[8] *Cryptococcus neoformans* is associated with animals and *Cryptococcus gattii* is more associated with certain trees and contaminated habitats.[8] Both pathogens cause cryptococcosis and are reported identically in death records. The pathogens are regionally focal. Fatal cases of cryptococcosis often involve fungal meningitis.[9] Cryptococcosis is one of the most significant opportunistic infections for human immunodeficiency virus (HIV) patients, with an incidence rate of 0.04% to 12% worldwide, and up to 70% mortality.[9] The death of a 42-year-old male on active duty was recorded in 1985. All other cryptococcosis deaths were retirees. Ninety-one percent of the deceased were male, with one recorded as "null." Most cases were reported in the 1990s (41.67%), which might be related to the acquired immunodeficiency syndrome (AIDS) epidemic.

Histoplasmosis: Histoplasmosis is a disease caused by *Histoplasma capsulatum*. It is a dimorphic soil fungus (*Emmonsiella capsulatum*) often associated with animal feces.[10] The parasitic form of histoplasmosis usually invades the lungs. Histoplasmosis is known to be one of the more common, yet very serious, fungal diseases in older Americans.[11] Histoplasmosis was considered

among the top 3 fungal diseases among Medicare recipients, with the highest mortality.[11]

Within our study period, we record 12 fatalities from histoplasmosis. Ninety-one percent of the fatalities were male. A 25-year-old woman serving as a USAF reservist was among the fatalities for histoplasmosis, as well as a 37-year-old active duty Airman. These deaths occurred in 1990 and 1991, respectively. The remaining 10 were male retirees aged from 62 to 89 years. The deaths occurred from 1971 to 2007, with 3 deaths in 1993. Proportionate mortality ratios for histoplasmosis as 1.2 from 1970-2010[1], indicating little to no difference between United States and Air Force proportionate mortalities. Hence, with the exception of the 2 individuals on active duty, the cases in retirees were predictable.

Mucormycosis/Zygomycosis: These diseases are caused by myriad species of Mucomycetes. We combined mucormycosis and zygomycosis deaths since they are both diseases caused by the same group of fungi. There are 7 records in the AFMR reporting mucormycosis/zygomycosis as the underlying cause of death. This is the second most common fungal disease in immunocompromised patients, but some opportunistic species infect immunocompetent hosts.[12,13] Unlike many of the fungal disease where a single or limited number of pathogens are known, mucormycosis is caused by a wide range of pathogens and thus has a wide geographic reach. A 27-year-old male active duty member was recorded with mucormycosis/zygomycosis as underlying cause of death. Seventy-one percent of cases occurred in the 1980s.

Pneumocystosis: Pneumocystosis is caused by *Pneumocystis jirovecii* or a related *Pneumocystis* spp.[1] *Pneumocystis* was described as a protozoan in older literature.[14] Pneumocystosis is rarely detected in healthy people, but up to approximately 70% of HIV-infected people have *P jirovecii* in their respiratory tract.[15] Almost all of the cases of pneumocystosis are in individuals with AIDS or with long-term immunosuppression. *Pneumocystis* pneumonia (PCP) was the defining opportunistic disease for two-thirds of AIDS patients in the United States during the onset of the AIDS pandemic.[15] The PCP-related fatalities in the USAF are consistent with the trends for the AIDS pandemic. Approximately one-third of deaths occurred in each decade. The first 2 pneumocystosis deaths in our study were reported in 1986, and there were 7 deaths total in that decade. There were 25 deaths in patients ranging in age from 35 to 80 years. The majority of deaths (n=13) occurred in the 1990s, with 5 deaths recorded since 2000. The most recently recorded pneumocystosis death in the AFMR was in 2012. Advances in antiretroviral drugs have greatly extended the lifespan and health of individuals infected with HIV. There were no female deaths recorded for pneumocystosis. All subjects with this underlying cause of death in our review were retired.

Sporotrichosis: This disease is caused by *Sporothrix schenckii*, and most infections are opportunistic, self-limiting, and cutaneous.[16] The primary route of infection is through cuts from fungus-contaminated wires, thorns, needles, etc. Among the fungal causes of death in the AFMR, sporotrichosis was the least common. Two deaths of retirees were recorded, with one disseminated infection and one that was unspecified in terms of body organ/region affected. Both men were aged in their 60s. Additional information was not available, but presumably they had compromised immune systems.

Unspecified Mycosis: Unspecified mycosis tied with candidiasis for the greatest number of deaths. While we do not have enough information on the deceased, a specific fungal agent was not investigated postmortem. Unspecified mycosis deaths contribute almost 20% of our data, with 43 deaths. The death of a 52-year-old male active duty member resulted from an unspecified mycosis; the remainder were retirees. Two of the 4 women in our review died from unspecified mycosis.

Based on the death records, the threat of fungal diseases to active duty Airmen is very low, and fatal cases are extremely rare. Women die less frequently from fungal infections, but are a smaller component of the military overall.

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# Does Reducing Time to Identification of Infectious Agents Reduce Incidence Rates of Norovirus in a Population Deployed to Southwest Asia?

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Abstract

During its deployment to Kuwait from 2011-2012, the 983rd Medical Detachment (Preventive Medicine) was augmented with a 4-person laboratory section which provided polymerase chain reaction capabilities not normally associated with an Army Level III preventive medicine detachment. Although common in many civilian laboratories, this was the first time this equipment was used by a deployed Level III Army preventive medicine detachment to identify an outbreak in this theater—it allowed rapid identification and description of a gastrointestinal disease outbreak caused by norovirus in Kuwait. The technology contributed to a decreased time required to identification of the causative agent (hours vs days) and thus the implementation of appropriate preventive measures. Based on this event, the authors suggest the addition of a modified laboratory section to the modified table of organization equipment for deployable preventive medicine detachments.

Branches of the US armed forces provide public health support through preventive medicine services that reflect the public health organization within the civilian sector. Military operations can be significantly degraded by infectious diseases of many types, including acute gastrointestinal (GI) illness outbreaks. Due to the nature of military operations and the requirement for sleeping, feeding and personal hygiene activities and facilities, service members are often at a high risk for rapid GI outbreaks.[1] George Washington, with one of his first general orders, required all of his officers to ensure all service members under them maintained themselves in a neat and clean manner and to stress to them the importance of hygiene to their overall health and ability to serve. The importance of preventive medicine continued to be discussed in subsequent years. In 1818, Dr Joseph Lovell was appointed the first Surgeon General of the newly created Army Medical Department. In the year prior to his appointment, Dr Lovell communicated to other physicians the need for an emphasis on the investigation of the causes of disease and on the implementation of preventive measures based upon knowledge, or ideas, of the causes of these diseases.[2]

While knowledge regarding the effects of disease on war fighting increased, disease and nonbattle injuries continued to be a major cause of mortality and morbidity in the US Army. During the Mexican War (1846-1848) the ratio of nonbattle to battle deaths was almost 7:1.[2] To help combat the effects of disease on military preparedness, 2 new divisions within the Surgeon's Office were developed: the Division of Sanitation and the Division of Infectious Diseases and Laboratories. By 1917, it was evident that a new category of officer was needed to support sanitation efforts in the Army. By presidential authority, the Act of May 18, 1917, created a sanitary corps of reserve officers with specialties outside of those typically considered medical professionals. This act effectively created the Reserve Medical Corps which led to the creation of the Medical Service Corps. From this point on, officers with specialties in epidemiology, sanitation, and other related fields were tasked with monitoring issues related to disease prevention.[2]

Initially, preventive medicine was mostly concerned with the prevention of disease and nonbattle injuries through enforcement of basic hygiene practices, food service sanitation and inspections, and vector control. This was the standard doctrine through at least the Cold War era. However, the Department of Defense formalized its efforts to collect environmental samples and other exposure data because of issues related to Agent Orange exposure during the Vietnam conflict and the lack of good exposure data for all the chemical agents and vaccines suspected of causing veterans' health problems after the Gulf War. To that end, preventive medicine was expanded in the late 1990s to include medical surveillance, specifically environmental and occupational

exposure assessments.[3] Preventive medicine detachments historically were separated into 2 types: sanitation detachments and entomological detachments. However, the Army Medical Department recently began a reengineering initiative which redefined the roles of preventive medicine. With the implementation of the reengineering, all preventive medicine functions were consolidated into one functional detachment type.[3] With this reorganization, the capabilities of the 2 detachment types were merged, providing more robust services (Table 1).

Table 1. Preventive Medicine Capabilities following the Army Medical Reengineering Initiative. Adapted from *Army Regulation 40-5* and Bosetti.[3,4]

| Medical Detachment, Preventive Medicine (Current) | |
|---|---|
| Mission | Provide preventive medicine support and consultation in the areas of entomology, DNBI prevention, field sanitation, sanitary engineering and epidemiology to minimize the effects of vector borne diseases, enteric diseases, environmental injuries, and other health threats to deployed US forces and their allies. |
| Basis of Allocation | 1 Detachment per 17,000 personnel. |
| Assignment | Assigned to a medical brigade or a medical group, and normally attached to an area support medical battalion or theater medical command. |
| Mobility | Unit is 100% mobile for all personnel and equipment in a single lift using its authorized organic vehicles. |
| Capabilities | Provides surveillance and control of disease vectors and reservoirs in assigned areas, including area and aerial spraying. Collected samples are forwarded to the nearest Level IV or Level V facility. |

Preventive medicine within the modern medical framework provides support at multiple levels. At the lowest level (Level I), individual service members and units are responsible for ensuring basic hygiene practices are followed to ensure health. Included in this level is the field sanitation team (FST), typically comprised of 2 to 4 personnel. Each company-sized element is required to have trained FST personnel trained by preventive medicine technicians and officers. Level II support is typically provided by one preventive medicine officer (AOC* 72D) and one preventive medicine technician (MOS* 68S). This support is usually at the brigade, division, or corps level. These personnel are responsible for ensuring support at Level I is adequate and functional. This is the first level at which preventive medicine personnel perform this function. At Level III is the Medical Detachment, Preventive Medicine (PM). The standard operational capabilities are listed in Table 1. Most deployable PM detachments follow a prescribed manning document. Based on the table of organization and equipment† (TOE), a fully manned PM detachment currently has 12 personnel. The specialties include one environmental science and engineering officer (AOC 72D), one entomologist (AOC 72B) and 10 preventive medicine technicians (MOS 68S). Lab capabilities are present with Level IV. Lab services at this level are provided by the Area Medical Laboratory (AML). The AML is the theater laboratory for confirmation of suspected disease agents identified by the Level III detachment. The AML is also responsible for shipping samples to laboratories in the United States. The AML is composed of 3 sections providing support to specific areas. These sections are (1) the endemic disease section, (2) the occupational and environmental health section, and (3) the nuclear, biological and chemical weapons section. These services are not typically provided by a Level III medical detachment. The final level of support is Level V which is provided by preventive medicine units in the United States. Support is also provided by the proponent agency for preventive medicine issues, the US Army Public Health Center (APHC). Definitive laboratory services are provided by the APHC.[4]

Within this framework, modern preventive medicine detachments, when deployed, address issues similar to those of their civilian counterparts. As level III support, PM units are very limited in their laboratory capacity, with most tests being for the presence or absence of pathogens, particularly in potable water. However, during any suspected disease outbreak, stool, food, water, tissue, or other samples are collected and submitted to the nearest Level IV or V facility. This causes long delays in testing and obtaining subsequent results, with typical turnaround times ranging from 8 to 21 days.[5,6] These delays lead to delays in implementation of control measures and may increase the incidence of cases. Also important, the potential for mission degradation is increased. The purpose of the present study was to determine if access to rapid real time PCR diagnostic capability at the detachment level, as described below, provided a diagnostic benefit to a deployed PM unit by reducing the time to identification of a causative agent and subsequent reductions in the incidence of GI illness compared to camps without such diagnostic capability.

## 983rd Medical Detachment (PM) Deployed Capabilities

On September 19, 2011, the 983rd Medical Detachment (PM) (MED DET (PM)), a US Army Reserve unit based at Fort Snelling, MN, was activated in support of

*AOC indicates area of concentration, MOS indicates military occupational specialty, both of which are medical skill designators.

†Table of Organization and Equipment: Defines the structure and equipment for a military organization or unit.

Table 2. Comparison of Standard and Enhanced Preventive Medicine Capabilities for the 983rd MED DET (PM).

| Standard MTOE Personnel (AOC/MOS)* | Enhanced MTOE(+) Personnel (AOC/MOS)* | Proposed MTOE Personnel(AOC/MOS)* |
|---|---|---|
| Environmental Science Officer (72D) | Environmental Science Officer (72D) | Environmental Science Officer (72D) |
| Entomologist (72B) | Environmental Science Officer (72D) | Entomologist (72B) |
| Detachment Sergeant (68S) | Entomologist (72B) | Microbiologist (71A) |
| Preventive Medicine NCO (68S) | Microbiologist (71A) | Detachment Sergeant (68S) |
| Preventive Medicine NCO (68S) | Biochemist (71B) | Preventive Medicine NCO (68S) |
| Preventive Medicine NCO (68S) | Preventive Medicine Physician (60C) | Preventive Medicine NCO (68S) |
| Preventive Medicine NCO (68S) | Detachment Sergeant (68S) | Preventive Medicine NCO (68S) |
| Preventive Medicine NCO (68S) | Preventive Medicine NCO (68S) | Preventive Medicine NCO (68S) |
| Preventive Medicine NCO (68S) | Preventive Medicine NCO (68S) | Preventive Medicine NCO (68S) |
| Preventive Specialist (68S) | Preventive Medicine NCO (68S) | Preventive Medicine NCO (68S) |
| Preventive Specialist (68S) | Preventive Specialist (68S) | Preventive Specialist (68S) |
| Preventive Specialist (68S) | Preventive Specialist (68S) | Preventive Specialist (68S) |
| | Preventive Specialist (68S) | Preventive Specialist (68S) |
| | Laboratory Technician (68K) | Laboratory Technician (68K) |
| | Laboratory Technician (68K) | |

*MTOE – modified table of organization and equipment
AOC – area of concentration
MOS – military occupational specialty

Operation Enduring Freedom ongoing in Kuwait. As previously mentioned, a typical detachment is comprised of 12 personnel with training in preventive medicine and one wheeled vehicle mechanic. However, for this mobilization, the deployment manning document was adjusted to provide enhanced capabilities. The detachment deployed 2 environmental science and engineering officers (AOC 72D), one entomologist (AOC 72B), one microbiologist (AOC 71A), one biochemist (AOC 71B), one preventive medicine physician (AOC 60C), 7 preventive medicine technicians (MOS 68S), and 2 laboratory technicians (MOS 68K), as shown in Table 2.

Corresponding with the additional personnel, the equipment inventory was augmented to include standard preventive medicine equipment and laboratory equipment. The additional equipment and personnel were intended to enhance diagnostic capabilities to the level typically found at the AML (Level IV) and at medical facilities in the United States (Level V). For example, nuclear, chemical and biological detection capabilities were increased by the addition of a hazardous material identification and hazardous air pollutant onsite gas chromatograph mass spectrophotometers (used for the identification of chemical hazards), identiFINDER radio-nucleotide monitors (FLIR Systems, Inc, Wilsonville, OR) and the Joint Biological Agent Identification and Diagnostic System (JBAIDS), which uses polymerase chain reaction technology for the identification of suspected biological warfare agents including those that cause anthrax, brucellosis, tularemia, and others (Table 3). Additionally, the provided equipment set included an Applied Biosystems Incorporated (Carlsbad CA) Model 7500 Fast Real-Time Polymerase Chain Reaction System (ABI 7500 FRT PCR). With the addition of the ABI 7500, the laboratory section of the 983rd MED DET (PM) was tasked with analyzing and typing suspected influenza samples collected from personnel presenting at the troop medical clinics. This data was used in the Department of Defense Global Emerging Infections Surveillance and Response System (DoD-GEIS) to globally track influenza subtypes and their effects on US military personnel. Lab-confirmed specimen results were coupled with demographic data and shared electronically on the GEIS web-based reporting systems. Initially, the ABI 7500 was used exclusively to analyze influenza samples for the DoD-GEIS program. However, it was soon realized that as a real-time PCR system, the ABI 7500 system had many advantages in laboratory confirmation and might be used in a broader mission, particularly monitoring for disease

Table 3. Initial Diagnostic Capabilities Using the JBAIDS and ABI 7500 Systems as of October 20, 2011.

| Target | System |
|---|---|
| *Bacillus anthracis* T1 | JBAIDS |
| *Bacillus anthracis* T2 | JBAIDS |
| *Brucella* | JBAIDS |
| *Burkholderia* | JBAIDS |
| *Coxiella burnetii* | JBAIDS |
| Eastern equine encephalitis virus | JBAIDS |
| *Francisella tularensis* | JBAIDS |
| Influenza virus A and B | JBAIDS |
| Influenza virus A SUBTYPING (H) | JBAIDS |
| Orthopox Viruses | JBAIDS |
| *Rickettsia prowazekii* | JBAIDS |
| Variola virus | JBAIDS |
| Venezuela equine encephalitis virus | JBAIDS |
| Western equine encephalitis virus | JBAIDS |
| *Yersinia pestis* T1 | JBAIDS |
| *Yersinia pestis* T2 | JBAIDS |
| Influenza virus A and B | ABI 7500 |
| Influenza virus A SUBTYPING (H) | ABI 7500 |
| Norovirus SEROGROUP 1 | ABI 7500 |
| Norovirus SEROGROUP 2 | ABI 7500 |

outbreaks, including gastroenteritis. At this time, the 983rd requested funds to purchase primer sets to expand the diagnostic capabilities of the ABI 7500 system to include many of the more common infectious agents related to gastrointestinal outbreaks (Table 4).

Table 4. Enhanced Diagnostic Capabilities Using the JBAIDS and ABI 7500 Systems as of April 20, 2012.

| Target | System |
|---|---|
| *Bacillus anthracis* T1 | JBAIDS |
| *Bacillus anthracis* T2 | JBAIDS |
| *Brucella* | JBAIDS |
| *Burkholderia* | JBAIDS |
| *Coxiella burnetii* | JBAIDS |
| Eastern equine encephalitis virus | JBAIDS |
| *Francisella tularensis* | JBAIDS |
| Influenza virus A and B | JBAIDS |
| Influenza virus A SUBTYPING (H) | JBAIDS |
| Orthopox Viruses | JBAIDS |
| *Rickettsia prowazekii* | JBAIDS |
| Variola virus | JBAIDS |
| Venezuela equine encephalitis virus | JBAIDS |
| Western equine encephalitis virus | JBAIDS |
| *Yersinia pestis* T1 | JBAIDS |
| *Yersinia pestis* T2 | JBAIDS |
| Influenza virus A and B | ABI 7500 |
| Influenza virus A SUBTYPING (H) (DoD-GEIS Project) | ABI 7500 |
| Norovirus SEROGROUP 1 | ABI 7500 |
| Norovirus SEROGROUP 2 | ABI 7500 |
| *Salmonella enterica* | ABI 7500 |
| *Giardia lamblia* and *G duodenalis* | ABI 7500 |
| *Campylobacter jejuni* | ABI 7500 |
| *Shigella flexneri* | ABI 7500 |
| *Yersenia enterolytica* | ABI 7500 |
| *Clostridium difficile* | ABI 7500 |
| *Vibrio cholerae* | ABI 7500 |
| *V parahaemolyticus* | ABI 7500 |
| *V vulnificus* | ABI 7500 |
| *Legionella* | ABI 7500 |
| Influenza virus A N1 subtyping | ABI 7500 |
| Influenza virus A N2 subtyping | ABI 7500 |
| Influenza virus 2009 N1 subtyping | ABI 7500 |

Based on the normal protocol for preventive medicine services, a Level III PM detachment would collect samples and send them to a Level IV or Level V lab for diagnosis and confirmation. For example, if a suspected food borne illness outbreak were to occur, the environmental science and engineering officer, in conjunction with PM technicians, would initiate a foodborne illness investigation. Because of the distance from these labs and the customs procedures for shipping biological samples, it took 2 or 3 weeks for results to be released. Due to the length of this delay, PM personnel were often left guessing as to the controls and steps which should have been implemented to address the outbreak. However, from start to finish, the typical turnaround time for a sample analyzed using the ABI 7500 is 4 to 6 hours. This drastic reduction in the time needed to identify the causative agent using the ABI 7500 system allowed members of the 983rd MED DET (PM) to implement control measures within 24 to 48 hours, thereby reducing the incidence and burden on the norovirus outbreak on service members in Kuwait during November, 2011 (Figure 1). The results and outcome of the usefulness of the enhanced capabilities of the 983rd MED DET (PM) in controlling the norovirus outbreak are reported below.

## Materials and Methods

Daily, routine monitoring of reported disease nonbattle injury (DNBI) was conducted through the Medical Situational Assessment Tool (MSAT) data base and the Joint Medical Workstation (JMeWS). The MSAT system is a theatre level application that combines information from multiple reporting locations throughout a defined area of responsibility. Data is reported by providers for individual encounters through the Medical Communications for Combat Casualty Care computer system. The JMeWS is a theater medical surveillance system which integrates health related information from all branches of the US military (Army, Navy, Air Force, and Marine Corps). Illnesses are coded using ICD-9* codes. During monitoring of these systems, all ICD-9 558 codes were reviewed and analyzed for gastrointestinal GI encounters reported by the provider. During suspected GI outbreaks in Kuwait and Iraq, suspected cases were defined as individuals reporting with nausea, diarrhea, or stomach cramps. Confirmation for cases in Kuwait was defined as those cases with the above symptoms as well as laboratory confirmation using real-time PCR via the ABI 7500 system by the laboratory component of the 983rd MED DET (PM). However, confirmation of cases in Iraq was defined as those cases with the above symptoms with laboratory confirmation conducted by laboratory personnel at Landstuhl Regional Medical Center, Landstuhl, Germany.

Concurrent with monitoring of digital reporting systems, members of the 983rd MED DET (PM) also monitored the use of over the counter medications (OTC) either provided for free from the pharmacies located at Camp Arifjan or Camp Beuhring, or purchased by personnel from the Post Exchange. During the suspected GI outbreak, pharmacy technicians at each camp in Kuwait provided a daily Excel spreadsheet showing the number of requests of OTC medications, specifically antidiarrheals such as Loperamide. Post Exchange personnel in Kuwait provided daily point of sale totals from each location for similar medications, such as Loperamide and Pepto Bismol.

Statistical analyses to compare disease rates between camps were conducted using SPSS and Excel statistical software packages. Chi-squares tests were performed to assess the similarity of the camp populations as described by age, class and sex. Chi-square tests were also performed to test for difference in daily incidence

*International Classification of Diseases, 9th Revision

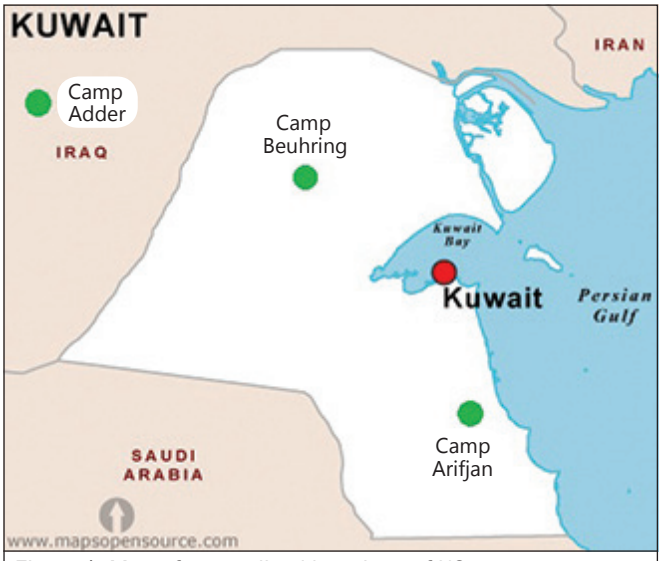


Figure 1. Map of generalized locations of US encampments of interest in Kuwait and Iraq, November 2011.

between camps. Additionally, ANOVA with least significant difference comparisons were conducted to compare mean incidence baseline and daily rates between the 3 camps. Attributable risk was calculated between Kuwait and Iraq camps to estimate the potential effect that camp location (and therefore access to rapid diagnostic testing) might have on outcomes.

## Results

Based on $\chi^2$ analyses, there was no difference in the makeup of camps by age or sex (Table 4). This is to be expected since military populations tend to be more homogenous than civilian populations. From November 1st through November 9th, the number of reported cases (suspected and confirmed) in Kuwait increased from a normal base level of 1 to 2 per day to a maximum of 18 on November 4. In Camp Adder, Iraq, a GI outbreak was documented from November 13 through November 19, 2011 (Figure 2).

Approximately 300 personnel located in Kuwait presented to sick call with acute gastroenteritis with symptoms which included nausea, prolonged watery stool, mild fever, and general malaise. Of those, 127 cases were reported at Camp Buehring and 88 cases were reported at Camp Arifjan. All others were from other camps located in Kuwait. Of all cases reported, 6 were confirmed through real-time PCR. During the documented outbreak in Camp Adder, 130 personnel reported to sick call with acute GI symptoms. Typical daily incidence rates for reported GI cases ranged from 0.00 to 0.76 per 1,000 personnel (CI±0.06) for Camp Buehring, 0.00 to 0.47 per 1,000 (CI±0.04) for Camp Arifjan and 0.00 to 0.67 per 1,000 (CI±0.07) for Camp Adder (Figure 3). These baseline rates were not significantly different ($P$=.63). During each outbreak, incidence rates increased rapidly (Figure 3). Based on a 7-day comparison during each outbreak, incidence rates for 6 of the 7 outbreak days were significantly higher at Camp Adder than at Camps Arifjan and Beuhring in Kuwait (all $P$<.02) (Figure 4). Camp Arifjan and Camp Beuhring incident rates were not significantly different (Table 2). Additionally, during the reported outbreak, a sharp increase in the request and use of medications specifically for gastrointestinal disorders was noted (Figure 5). The increase in the use of OTC medication corresponded with increases in reported GI cases through daily DNBI monitoring. At peak use, the distribution of OTC medications was significantly higher than the baseline ($P$<.001).

To determine what effect the utilization of the laboratory in Kuwait might have had on the incidence of norovirus in Kuwait and Iraq, attributable risk was a calculated. For these calculations, exposure was assigned to camps

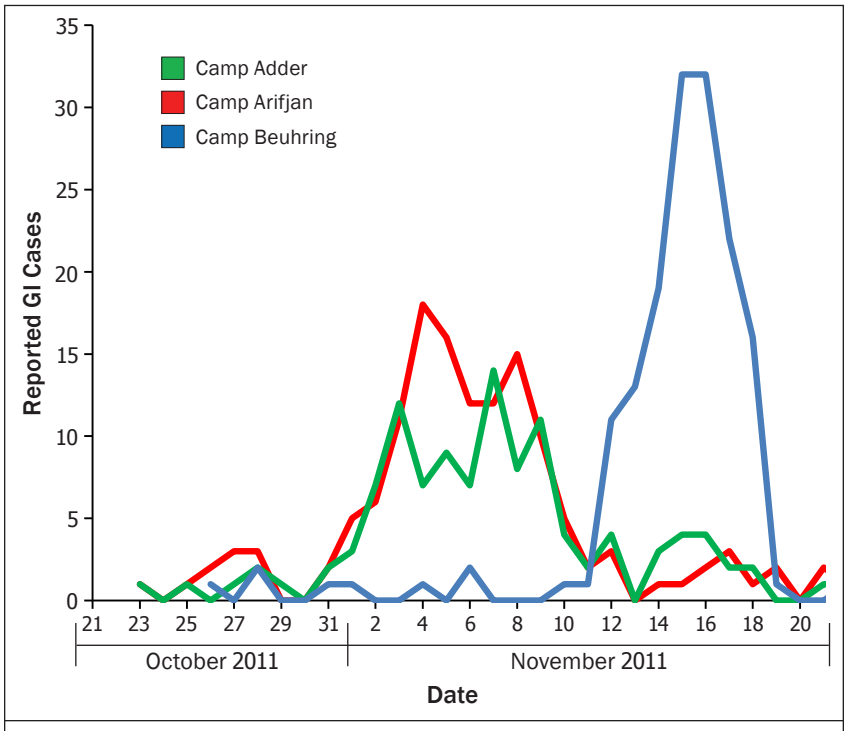


Figure 2. Number of cases reporting to sick call with GI complaints for the period October 22, 2011, through November 21, 2011. The clinics are not open on Sundays, which caused an apparent decline in the number of personnel reporting for November 6 and November 13. Cases overall were significantly different between camps ($P$<.001); however, only Camp Adder was significantly different when compared to Camps Arifjan and Beuhring ($P$<.003).

in Kuwait where rapid laboratory identification was available. Iraq, where any stool or food sample had to be shipped and analyzed by normal protocols, was set as unexposed because it did not have the rapid diagnostic capability. Attributable risk was calculated as 0.664 indicating that 66.4% of all cases of norovirus in Iraq could be attributed to the lack of rapid laboratory diagnostic services and subsequent delay in the implementation of controls (Table 5).

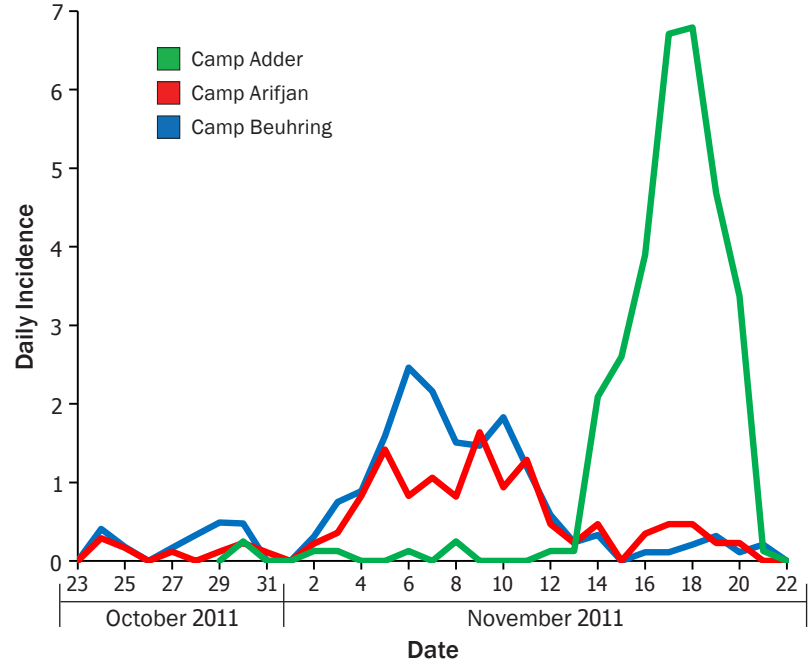


Figure 3. Reported daily incidence per 1,000 service members for the period October 22, 2011, through November 21, 2011. Daily incidence at Camp Adder were significantly different than daily incidence at the other 2 camps ($P < .02$).

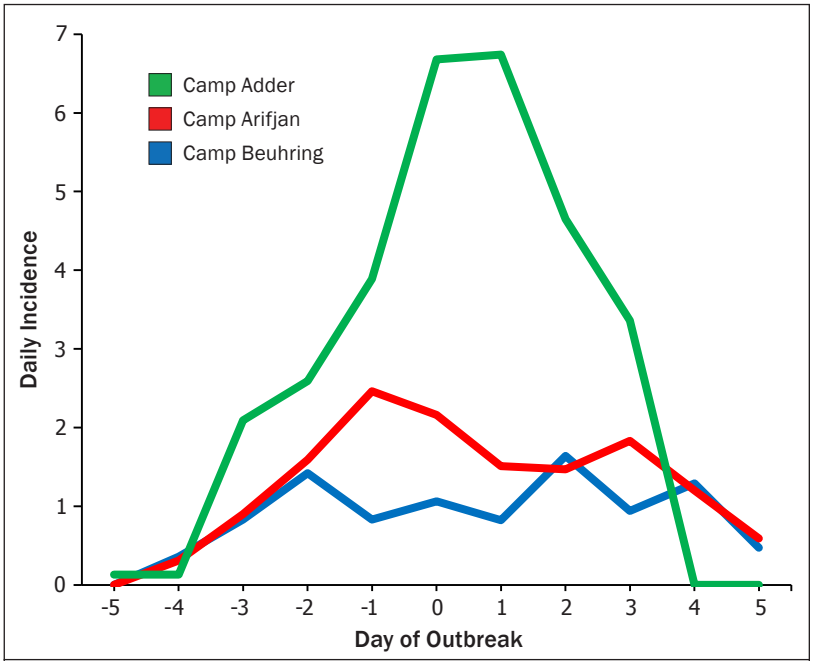


Figure 4. Reported daily incidence per 1,000 service members aligned by peak incidence per camp. Daily incidence at Camp Adder were significantly different than daily incidence at the other 2 camps ($P < .02$).

## COMMENT

Norovirus is a nonenveloped, positive sense, single stranded RNA virus which can cause acute gastroenteritis in humans. The virus is responsible for the GI outbreaks noted on cruise ships and in other areas where humans are densely located. Outbreaks in military settings have also been reported in Iraq, Afghanistan, and aboard naval vessels.[5] The virus is highly contagious and can cause symptomatic reactions with an exposure dose as low as 100 viral particles. The primary route is fecal-oral, either by person-to- person contact or through indirect contact via surface contact with contaminated food, water or fomites.[6] It can also be spread through aerosolized particles produced via vomiting. The virus is relatively stable and has been known to persist in the environment for several days. The average incubation period is 12 to 48 hours. Symptoms include acute-onset vomiting, watery nonbloody stool, headache, low grade fever, and general malaise.[1] Symptoms can persist for 24 to 60 hours and reinfection can occur. A person can be asymptomatic but still be infectious through shedding of viral particles. Additionally, infections with norovirus do not confer any lasting immunity. While often self-limiting, norovirus outbreaks can persist with conditions typically found in military settings, especially when service members are deployed. Camp Arifjan and Camp Buehring were mostly populated with service members assigned to units mobilized to Kuwait for 9 to 12 months. Members assigned to these units typically were housed together in discrete areas of the camps. However, with the influx of personnel during the movement out of Iraq, personnel from different units were comingled and housed where space allowed. This made it difficult to determine a specific index case or any trends in incidence of norovirus caused illness by unit. As the number of personnel increased, the fixed facilities of each camp quickly became inadequate for the number of personnel present. For example, ideally each service member is allocated at least 72 square feet of living space. At

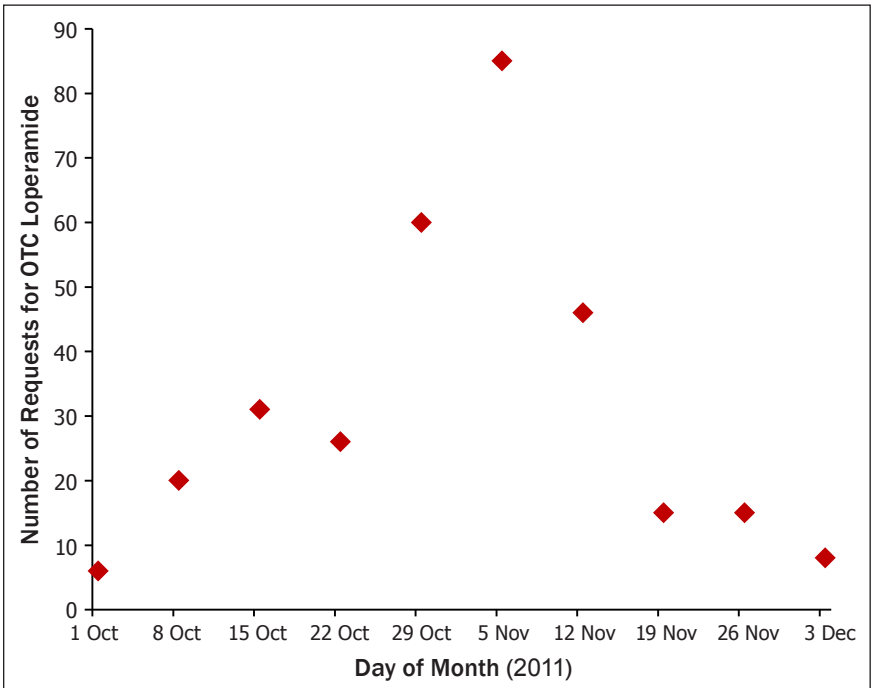


Figure 5. Number of requests for over-the-counter bottles of the antidiarrheal drug Loperamide given through the Camp Arifjan pharmacy. Results are tabulated weekly. Requests for Loperamide began to increase the week of October 8, approximately 3 weeks prior to documented increases in the number sick calls for acute GI complaints. Peak requests were significantly greater than baseline requests ($P < .001$).

the height of troop densities, most service members on Camp Buehring were allocated 36 to 40 square feet of living space. Concurrently, the ratio of latrines and hand washing sinks available for use on Camp Buehring went from 1 for every 10 personnel to 1 for every 30 personnel. Initially, cleaning contracts were not amended, resulting in latrines being cleaned only twice per day (every 12 hours). Within 4 or 5 hours of a cleaning cycle, most latrines were overflowing, and had no soap, water, or hand sanitizer available. Also, during this time, there was only one dining facility (DFAC) open resulting in long lines. Prior to entering any DFAC, personnel were required to wash their hands. However, because the lines were so long, only 20% to 30% of the personnel entering the DFAC were observed washing their hands. Within the DFAC, the fruit and salad bar and drink dispensers were self-serve operations. Because personnel were not washing their hands after using the latrine or when they entered the DFAC, the utensils used to serve salads and fruit and cups on the drink serving line became excellent sources for transmitting the virus. The door handles entering the DFAC were also potential sources for hand-to-mouth transmission of the disease.

Rapid identification of norovirus as the causative agent by real-time PCR in the 983rd MED DET (PM) Infectious Disease Lab allowed for a rapid response to the outbreak. Primer sets for norovirus were included in the turnover of the ABI 7500, and were thus already part of the 983rd's laboratory capabilities, which allowed positive confirmation of norovirus type 1 within 6 hours of receipt of the first stool specimen. Because neither the troop medical clinic nor hospital laboratories possessed diagnostic capabilities for norovirus, any stool samples collected from either laboratory would normally be sent to Landsthul Regional Medical Center (LRMC) in Germany for analysis. The typical turnaround time for results from LRMC was one to two weeks. By using the ABI 7500, the time for confirmation was reduced from weeks to hours (Table 6).

Once confirmation occurred, the 983rd MED DET (PM) implemented specific controls that reduced the scope and magnitude of the outbreak. Strict hand washing protocols were implemented which included observing all personnel entering any food establishment. If personnel did not wash their hands prior to entry, they were denied access to rations and were given a counseling statement which was added to their records. Random checks of hand washing after latrine use were also done. Concurrently, in coordination with public affairs personnel of US Central Command (CENTCOM), the

Table 5. Distributions by age and sex are similar across all camps and to the overall Army-wide values. No significant difference in age by class or gender distribution occurred among the 3 camps.

| Patient Age (Years) | Camp Arifjan (Kuwait) | Camp Bheuring (Kuwait) | Camp Adder (Iraq) | Cumulative | Army-wide |
|---|---|---|---|---|---|
| ≤25 | 41.2% | 42.7% | 43.0% | 42.3% | 42.7% |
| 26-30 | 23.0% | 23.2% | 22.7% | 22.7% | 23.0% |
| 31-35 | 13.7% | 14.6% | 14.6% | 14.6% | 14.7% |
| 36-40 | 10.3% | 9.8% | 10.5% | 10.5% | 10.6% |
| ≥41 | 10.9% | 9.7% | 9.3% | 9.9% | 9.1% |
| Patient Gender | n=117 | n=82 | n=128 | N=327 | N=1,105,301* |
| Male | 85.5% | 84.1% | 85.2% | 85% | 85.4% |
| Female | 14.5% | 15.9% | 14.8% | 15% | 14.6% |

*Includes Active, Reserve, and National Guard components.

983rd MED DET (PM) Command produced a public service announcement on the outbreak and the need for proper hand washing and hygiene. Contracted cleaning staffs were trained on the use of a chlorine solution for sanitation of all bathroom surfaces. This sanitation occurred at least 3 times per day. Through dissemination of strict hand washing requirements via public service announcements, the outbreak was limited in the number of personnel affected, resulting in fewer days lost and no loss in mission capability.

The number of affected personnel in Kuwait was kept to approximately 2.2% of the total population at the time and the duration of the outbreak was less than 2 weeks (Figure 3). While the duration of the outbreak was approximately 3 days longer than the outbreak in Camp Adder, the number of affected personnel on any one camp in Kuwait was less than the number affected on Camp Adder. Additionally, the daily incidence rate for reported GI patients was less for camps in Kuwait compared to Camp Adder. Similar outbreaks in other theatres of operation also affected a greater percentage of the total population. For example, an outbreak in Qatar resulted in approximately 300 personnel contracting the virus out of a total camp population of 1,250. All changes in protocols and enforcement which mitigated the outbreak were a direct result of the rapid identification of norovirus as a causative agent.

Ultimately, laboratories are the cornerstone of disease diagnosis for public health. Routine patient testing is now largely performed by clinical laboratories; however, the results of these tests are needed by public health for surveillance, outbreak investigations, and disease control. This is a core function of public health laboratories. This core function requires accurate and timely data. To improve the accuracy and timeliness of testing and reporting, clinical laboratories should work closely with public health laboratories, with each complementing the capabilities of the other.[7] Historically, laboratory testing for specific pathogens involved the use of clinical tests based on bacterial plating techniques or tests for specific toxins. Many of these tests, while cheap, required days to weeks to complete, extending the time for implementation of specific interventions designed to reduce or limit the disease burden.[8,9] All of the steps necessary for investigation and reporting between onset of symptoms and a public health response delay the recognition of an outbreak and an appropriate response.

To effectively control disease outbreaks, it is critical that rapid detection occurs. Rapid detection of the causative agent allows for earlier containment. Paramount to this identification is the development and use of DNA/RNA and protein technology which give rapid, sensitive and accurate diagnoses on what microbe or virus is responsible. Real-time PCR systems have the potential to accurately and rapidly identify pathogenic organism not only by species, but also by the strain of the organism. The rapid detection and response by public health officials, whether military or civilian, to a suspected outbreak continues to be a major concern.[10] Because the time to detection and identification is the most critical concern, real-time PCR has the potential to positively affect public health. Because real-time PCR systems

Table 6. Comparison of typical versus enhanced laboratory timelines to confirmation of causative agent for typical GI outbreaks. Civilian and military timelines are similar when using the typical confirmation timeline. The timelines demonstrate that the availability of a laboratory capability embedded in a deployed PM detachment reduces the time required for confirmation from weeks to hours.

| **Typical timeline (days) for confirmation of causative agent for typical GI outbreaks following sample collection by a civilian clinic or health department facility.[a]** | | **Timeline (hours) for confirmation of causative agent with laboratory capability embedded in deployed PM detachment.** | |
|---|---|---|---|
| **Process** | **Days (cumulative) to completion of process after collection of sample** | **Process** | **Hours Required** |
| Receipt of stool samples | 2-4 | Receipt of stool samples after collection by provider | 1-2[b] |
| Results of initial stool sample culture | 5-8 | Molecular subtyping | 4-6 (after receipt of sample) |
| Case report to health department | 7-9 | Positive confirmation of causative agent | 5-30 (cumulative following sample collection, depending on time required for receipt) |
| Isolate submission to public health laboratory | 8-10 | | |
| Interview | 12 for E coli<br>14 for *Salmonella*<br>18 for *Campylobacter* | | |
| Molecular subtyping | 15 for E coli<br>18 for *Salmonella*<br>21 for *Campylobacter* | | |

[a] Closely comparable to the 8-21 days typically required when samples gathered in deployed locations must be shipped to an Area Medical Laboratory or Army Public Health Center laboratories in either Landstuhl, Germany, or Aberdeen Proving Ground, Maryland.

[b] Time required if provider notifies PM of sample collection, and PM retrieves sample. Otherwise, it may require up to 24 hours for receipt.

are able to produce results in as little as one hour, the speed at which a causative agent is identified is drastically reduced compared to classic laboratory diagnostic techniques (days to weeks).[9] In conjunction with enrichment techniques, real-time PCR has the potential to not only provide accurate, reliable, and quick diagnostics, but also quantification of the pathogen load when used to test foods for possible contamination.[9] This could provide even more data for the investigation of foodborne disease outbreaks. Critical to our ability to respond to disease outbreaks is the rapid and continual development of scientific technology. These advances will be the foundation for the response by public health to emerging and infectious disease outbreaks. For infectious diseases, applying genomics and proteomics to the determination of the disease source (causative agent) will be critical.[11]

The rapid and successful identification and mitigation of the Kuwait norovirus outbreak generated an appreciation for the potential utility of this system when integrated into the preventive medicine mission. With this in mind, a request was presented to CENTCOM to expand the diagnostic capabilities of the 983rd laboratory through the purchase of additional real-time PCR primer sets for known causative agents of gastroenteritis. Based on the results of the norovirus outbreak, CENTCOM agreed with the proposed expansion of diagnostic capabilities. Based on known or suspected agents of foodborne illnesses in Kuwait, the 983rd increased GI diagnostic capabilities by nearly 5-fold and overall diagnostic capability by almost 100% with minimal cost (approximately $3,000) (Table 4). These additional primer sets allowed for the identification of 5 additional pathogens associated with cases of GI illness in Kuwait. This expanded capability is unique for a forward deployed PM detachment, but has the potential to improve services provided in the deployed area of operations.

Real-time PCR is an important tool for forward deployed laboratories involved in disease monitoring and control. Two systems were available during this mobilization: JBAIDS and the ABI 7500. The JBAIDS has the advantage of portability and ambient reagent storage, but it also has the significant disadvantages of reagent cost, short shelf-life (6-12 months), and compatibility with only specific reagent kits. The ABI 7500 system, on the other hand, is not easily portable and requires some reagents to be stored cold or frozen, but such reagents are significantly less costly and may be stored frozen almost indefinitely. Also, the ABI 7500 may be adapted for a very large number of applications.

The success in controlling the norovirus outbreak, demonstrated by reduced incidence rates in Kuwait compared to Iraq, illustrates that the Army Medical Department should consider permanent changes to the deployable preventive medicine modified TOE to include a 2-person laboratory section and the ABI 7500 system with appropriate support equipment, reagents, and primer sets. This system has the potential to positively affect service member health and mission readiness while deployed by decreasing the time for diagnostic confirmation of many diseases of military importance.

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# Hearing Loss and Tinnitus in Military Personnel with Deployment-Related Mild Traumatic Brain Injury

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## Abstract

The objective of this study was to analyze differences in incidence and epidemiologic risk factors for significant threshold shift (STS) and tinnitus in deployed military personnel diagnosed with mild traumatic brain injury (mTBI) due to either a blast exposure or nonblast head injury. A retrospective longitudinal cohort study of electronic health records of 500 military personnel (456 met inclusion criteria) diagnosed with deployment-related mTBI was completed. Chi-square tests and STS incidence rates were calculated to assess differences between blast-exposed and nonblast groups; relative risks and adjusted odds ratios of developing STS or tinnitus were calculated for risk factors. Risk factors included such characteristics as mechanism of injury, age, race, military occupational specialty, concurrent diagnosis of posttraumatic stress disorder (PTSD), and nicotine use. Among blast-exposed and nonblast patients, 67% and 58%, respectively, developed STS, ($P$=.06); 59% and 40%, respectively, developed tinnitus ($P$<.001). Incidence of STS was 24% higher in the blast-exposed than nonblast group. Infantry service was associated with STS; Marine Corps service, PTSD, and zolpidem use were associated with tinnitus. Unprotected noise exposure was associated with both STS and tinnitus. This study highlights potential risk factors for STS and tinnitus among blast-exposed and nonblast mTBI patient groups.

Traumatic brain injury (TBI) is an invisible injury of war that has been identified as the "signature injury" of Operations Iraqi Freedom (OIF) and Enduring Freedom (OEF).[1-8] Between 2000 and 2015, the Department of Defense (DoD) diagnosed 333,169 cases of TBI in US service members worldwide across all services and duty statuses, with an estimated 20% of these diagnoses made in deployment settings. Approximately 82% of the total diagnoses during this period were classified as mild.[9] Common mechanisms of injury (MOI) for TBI experienced by military personnel are blast exposure or nonblast events, occurring either in isolation or combination. It is estimated that blast exposure is responsible for approximately 75% to 80% of all combat injuries in both OIF and OEF.[10,11] Common deployment-related events that can result in blast-exposed TBI include the detonation of improvised explosive devices (IEDs), rocket propelled grenades (RPGs), vehicle borne improvised explosive devices (VBIEDs), and mortars; while common events that can result in a nonblast TBI include motor vehicle accidents, falls, assaults, rapid acceleration/deceleration, and sports/recreation training exercises.[12,13] Multiple studies have shown a pattern of sensory impairments including hearing loss and/or tinnitus in the presence of mTBI.[3,5,6,8,13-18]

Service in the US military often exposes an individual to high-intensity and hazardous noise levels, which are known risk factors for both hearing loss and tinnitus. The Department of Veterans Health Administration has identified tinnitus and hearing loss as the number 1 and 2 service connected disabilities, respectively, every Fiscal Year since 2007.[19-25] Tinnitus is estimated to have a prevalence rate of 30.8% among Veterans of OIF, OEF, and Operation New Dawn (OND). While the estimated prevalence of hearing loss in Veterans of current conflicts is reported at 7.3 to 26.6%, an increase from 0.8% in 2003 and 2.2% between 2004-2009.[10]

Deployed service members are exposed to both military-unique and industrial noise hazards, which would warrant the use of a hearing protection device (HPD). Additionally, military personnel and the civilians who serve alongside them are frequently exposed to hazardous noise levels that are often higher than those measured in most industrial occupational environments.[26] Examples of military unique noises include weapon systems, blast exposures, fixed- and rotary-wing aircraft, and tracked and wheeled vehicles, while common high intensity industrial noise hazards include sources such as power tools, generators, and/or machinery.[26,27]

Hazardous noise exposures experienced in combat may exceed intensity levels against which the issued HPD can protect, and therefore still cause auditory damage even when the HPD is in use.[28]

Deployments with and without combat experience have been shown to have an association with injury to the ear and/or auditory system. Specifically, military deployment has been associated with acoustic trauma, permanent threshold shifts, tinnitus, tympanic membrane (TM) perforation, and/or an H3 to H4 hearing profile (ie, a moderate to profound hearing loss with aided speech reception thresholds greater than 30 dBHL (decibel hearing level)).[28] Additionally, military deployment with combat experience has been shown to increase the likelihood of reporting hearing loss by 1.6 times over that of service members who were not deployed and did not have combat experience.[29]

Those deployed service members who are blast-exposed from the detonation of IEDs in OIF and OEF have also been shown to be at a significantly higher increased risk of acquiring a hearing loss.[29] Additionally, hearing loss and tinnitus are thought to be overlooked and underreported when such injuries occur in conjunction with life-threatening injuries in polytraumatic events. Although blast exposures typically inflict head injuries, much is unknown regarding the prevalence of blast-related ear trauma (ie, hearing loss or central auditory processing difficulties).[10,11] However, blast-related auditory injuries among US military personnel during deployment account for as many as 78% of injuries. Detonation of explosives such as IEDs, RPGs, and VBIEDs not only expose military personnel to a blast overpressure wave, the individual may also subsequently be exposed to hazardous noise levels, ototoxic agents within the blast wave, combined effects of inhaled toxins with hazardous noise levels, and ototoxic medications used to treat sustained illness or injuries within the deployed environment.[28,30] Recovery from hearing loss to preblast exposure levels may take hours to week(s), which can compromise situational awareness and operational readiness.[7,31] Soldiers have reported an immediate decrease in hearing sensitivity and/or a new awareness of tinnitus post-blast exposure.[7,16,31,32]

Combat-related blast exposure may be unpredictable in onset and length. A service member who cannot anticipate a blast and is not using an issued HPD is unprepared and/or unprotected against the blast overpressure wave and hazardous noise levels to the auditory system, increasing the likelihood of acquiring an acoustic injury. A previous study found that blast exposure of deployed Soldiers who were were not using an HPD resulted in a significant and mixed hearing loss (ie, conductive and sensorineural).[32] However, use of an HPD at the time of blast-exposure does not prevent damage to the ear, as there is reported evidence of TM perforation with use of an HPD.[33]

Tinnitus is a known symptom associated with mTBI, both with and without loss of consciousness. A head injury with resulting mTBI increases the patients' likelihood of reporting tinnitus by 1.70 times compared to other non-head injuries.[34] Oleksiak et al found a self-reporting rate of 59.5% for difficulty hearing and 75.7% for tinnitus among sampled Veterans diagnosed with mTBI during 2007-2009.[8] Dougherty et al reported that military personnel were 4 times more likely to report tinnitus in the presence of a TM rupture and 17% more likely in the presence of a concomitant head injury.[31] Lew et al reported a 38% prevalence of tinnitus in patients with blast-exposed TBI.[15] Additionally, use of an HPD was found to reduce by 43% the likelihood of a middle or inner ear injury involving tinnitus diagnoses.[31]

Epidemiologic studies are beneficial in audiology because they:

- Establish causation for hearing loss and tinnitus acquired during deployment.
- Identify risk factors that may further decrease hearing sensitivity or factors that increase risk to developing tinnitus.
- Identify environmental factors that may increase the likelihood of acquiring a hearing loss or tinnitus.

While epidemiologic studies of hearing loss and/or tinnitus acquired from military service within the active duty and veteran populations during these recent operational conflicts are limited, Theodoroff et al provided a comprehensive review of hearing loss prevalence and risk factors associated with US service members and Veterans who served in OIF, OEF, and/or OND.[10]

McIlwain et al reported the effects of blast exposure and HPD use and subsequent acoustic trauma in deployed US Army Soldiers serving in OIF.[32] A significant difference in audiometric thresholds at 500 Hz, 1000 Hz, and 2000 Hz between those blast-exposed using HPD and nonblast was found. Additionally, a significant difference was noted at audiometric octave frequencies 500 Hz to 12,000 Hz between those blast-exposed who did not wear HPDs and an unexposed control group. The Millennium Cohort Study on hearing loss, one of the larger prospective studies providing audiometric data from US military personnel, reported that personnel with combat-related head injury were 7 times more likely to have new-onset hearing loss than personnel

without such head injury.[29] Additional risk factors that increase a service member's likelihood of acquiring an ear injury include gender (male), age (greater than 40 years), and rank (officer).[35]

The known association between deployment-related mTBI and MOI with changes in hearing sensitivity (ie, audiometric thresholds) and/or tinnitus in active duty or reservist service members is limited in scope. Previous studies have analyzed: hearing sensitivity in combat Veteran populations after separation from service[5,8,14,15,17,36,37]; specified MOI, with no discussion of TBI[15,36,37]; TBI without identifying the degree of severity[30]; and mTBI with unspecified MOI.[8,17] The purpose of this retrospective cohort study was to explore risk factors associated with tinnitus and hearing loss in a cohort of service members who were diagnosed with deployment-related mTBI. This cohort was divided into exposure groups (blast and nonblast) to compare the risk factors for hearing loss and tinnitus between the 2 groups.

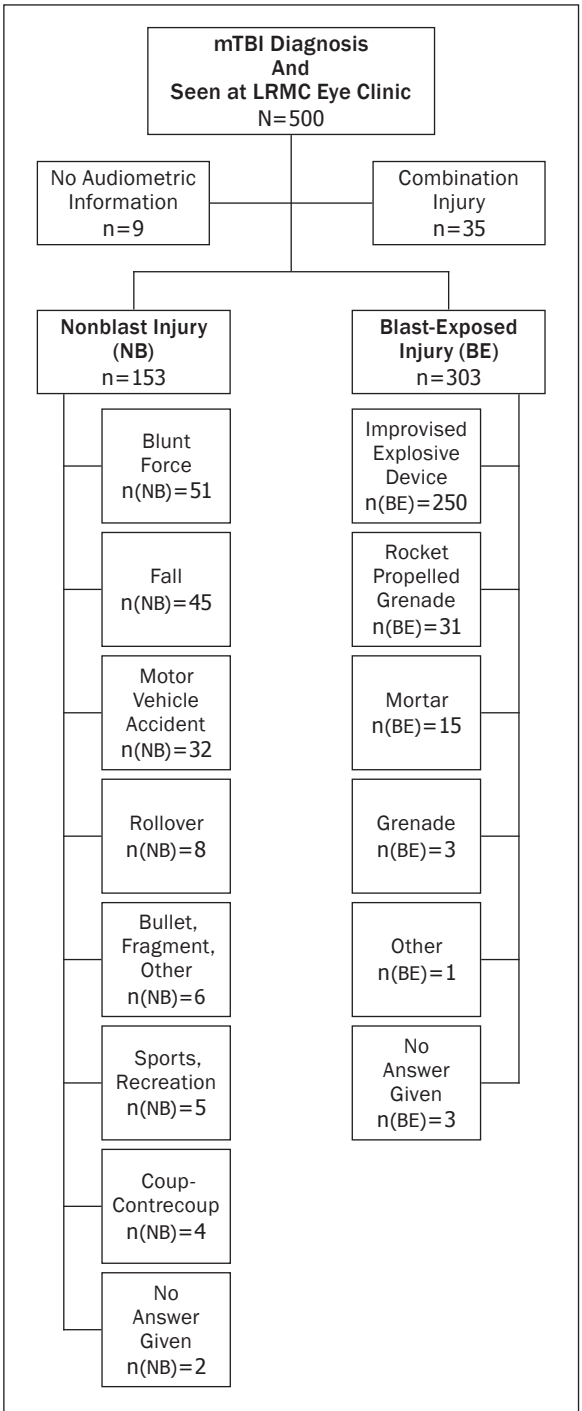
## Methods

### Study Population

This study was an addendum to a study completed at Landstuhl Regional Medical Center (LRMC) of patients with mTBI who received care by the TBI Recovery interdisciplinary team (ie, neurology, optometry, ophthalmology, audiology, physical therapy, occupational therapy, and behavioral health).[38] The study was approved by the Brooke Army Medical Center Institutional Review Board and US Army Medical Research and Materiel Command Office of Human Research Protection.

The current study was designed as a longitudinal audiologic retrospective electronic health record chart review of 500 military personnel diagnosed with deployment-related mTBI. Records were stratified by MOI, with 456 of 500 meeting inclusion criteria as illustrated in the Figure. Criteria for inclusion were US military personnel who:

1. Sustained a head injury resulting in the diagnosis of deployment-related mTBI by a neurologist within the TBI Recovery Team at LRMC;
2. Were treated between January 2008 and February 2011;
3. Had at least one audiometric test record within the military electronic health record (AHLTA) and/or Defense Occupational and Environmental Health Readiness System Data Repository (DOEHRS-DR) (9 personnel were excluded for not having either a DoD Form 2215 (DD 215), a DD 2216, or clinical audiogram); and




Study cohort distribution of mechanism of injury.
mTBI indicates mild traumatic brain injury;
LRMC, Landstuhl Regional Medical Center.

4. Recorded MOI of either blast-exposed or nonblast (35 people were excluded for sustaining a combination injury, ie, blast-exposed plus nonblast head injury).

Participants were either medically evacuated from theater or stationed in the vicinity of LRMC and referred

by their primary care provider to the TBI Clinic. The diagnosis of mTBI was based on DoD criteria: loss of consciousness of no more than 30 minutes, posttraumatic amnesia of no more than 24 hours, alteration in mental state, a Glasgow Coma Scale score from 13 to 15, and normal structural brain imaging.[9]

### Measures

The study analyzed audiometric threshold information occurring at 5 common points in time during which the deployed service member encountered a DoD audiologist and/or Army Occupational Hearing Conservation Technician. In chronological order, audiograms that were collected and analyzed include:

1. Reference audiogram upon entry to service (ie, DD 2215 or DD 2216 (line 15c));
2. Predeployment DD 2216;
3. LRMC clinical audiogram completed 0-90 days postinjury;
4. Postdeployment DD 2216 or LRMC Clinical audiogram completed 90 days or more following injury, whichever was first; and
5. The last DD 2216 on record.

Clinical audiograms completed at the Audiology Clinic at LRMC were obtained from AHLTA, and hearing readiness audiograms (ie, DD 2215 and DD 2216) were obtained from the DOEHRS-DR.

Hearing loss was quantified by identifying and calculating STS for each participant record between the test of interest (ie, predeployment, LRMC, postdeployment, last on record) and the reference audiogram. The STS was defined according to the 1998 version (now superseded) of the *Department of Army Pamphlet 40-501*, as that was the edition governing the Army Hearing Program at the time of service delivery. A STS in hearing is defined as a change in at least one ear noted between the test of interest and reference audiogram as either an average at 2000 Hz, 3000 Hz, and 4000 Hz of ±10dBHL or more, or ±15 dBHL or more at 1000 Hz, 2000 Hz, 3000 Hz, or 4000 Hz.[39]

Tinnitus was quantified by querying the participants' AHLTA/DOEHRS-DR record for a previous diagnosis or record of tinnitus in at least one ear. Demographic and clinical characteristics were also queried from DOEHRS-DR for analyses. Demographic information included gender, duty status, branch of service, rank, military occupational specialty (MOS), age, and race/ethnicity. Clinical characteristics that were obtained include diagnoses of PTSD, sleep problems, hyperacusis/noise sensitivity, total number of previous TBIs, and prescription or over-the-counter medication use. Details of injury characteristics were also captured, including mounted/dismounted status, conflict in which the service member was injured (OIF or OEF), and total number of previous deployments.

### Statistical Analysis

In addition to audiometric information, demographic and clinical history data reported in the LRMC medical record for each patient were collected, coded, and entered into an Excel spreadsheet. Prescription and over-the-counter medications used by each patient and reported in the medical record were also captured in the spreadsheet, which was imported into SPSS version 21 (IBM Corp, Armonk, NY) for descriptive analysis of the demographic variables, and also into SAS version 9.1.3 (SAS Institute Inc, Cary, NC) for bivariate and multivariate analysis of each demographic or clinical variable with respect to blast exposure status, STS, or tinnitus. A $\chi^2$ test was performed to determine the statistical significance of association between each categorical demographic or clinical variable and blast exposure status. The relative risk (RR) with 95% confidence interval (CI) of developing an STS or tinnitus was calculated for each demographic or clinical characteristic. An independent samples *t* test was performed to determine if the difference in mean age between the blast-exposed and nonblast groups was statistically significant.

The date on which each audiogram was completed is recorded on DD 2215 and DD 2216. Consistent with the retrospective cohort study design used in the current study,[40] these dates were used to calculate person-time during which patients were at risk of developing an STS. The amount of person-time contributed by each patient to the study was calculated by subtracting the date of the reference audiogram from the date of the audiogram on which an STS was first identified (or the date of the last audiogram on file if the patient did not develop an STS). For each patient, the number of elapsed days between the 2 dates was divided by 365.25 and summed across all patients to obtain the total person-years at risk, which serves as a denominator for calculating incidence rates of STS. The number of STS cases in each subgroup (blast-exposed and nonblast) was divided by the total person-years in each group and multiplied by 1,000 to calculate the incidence rate of STS per 1,000 person-years for each group. The rate for the blast-exposed group was divided by the rate for the nonblast group to calculate a rate ratio comparing the incidence rates between the 2 groups.

Finally, to adjust for multiple demographic and clinical variables simultaneously, 2 multiple logistic regression models were constructed for multivariate analysis, one

with STS as the dependent variable and the other with tinnitus as the dependent variable, using forward selection of variables with the significance level for entry into the models set at 0.05. Age was divided into 4 groups (quartiles) to enable categorical analysis, with patients aged 18 to 22 years (youngest quartile) serving as the reference group. The adjusted odds ratio (OR) (95% CI) of developing STS or tinnitus was calculated for each statistically significant covariate entered into the logistic regression models.

## Results

### Demographic and Clinical Characteristics

Table 1 shows the demographic characteristics of patients by blast exposure status. On average, blast-exposed patients were younger (mean age 27.8 years) compared to nonblast patients (mean age 30.6 years), with greater percentages of males, Marine Corps service, and enlisted personnel. Compared to nonblast patients, greater percentages of blast-exposed patients served in the infantry, were dismounted at the time of injury, and had been deployed two or more times. No statistically significant differences in race, duty status, and conflict at the time of injury were found between blast-exposed and nonblast patients.

Table 1. Patient Demographic Characteristics by Blast Exposure Status.

| Characteristic | Total (%N) N=456 | Blast (%n) n=304 | Nonblast (%n) n=152 | *P* value |
|---|---|---|---|---|
| Age, year (mean±SD) | 28.8±8.1 | 27.8±7.6 | 30.6±8.7 | .001 |
| Sex | | | | <.001 |
| Male | 416 (91%) | 298 (98%) | 118 (78%) | |
| Female | 40 (9%) | 6 (2%) | 34 (22%) | |
| Race | | | | .14 |
| White | 312 (68%) | 208 (68%) | 104 (68%) | |
| Black | 71 (16%) | 42 (14%) | 29 (19%) | |
| Hispanic | 52 (11%) | 41 (13%) | 11 (7%) | |
| Other | 21 (5%) | 13 (4%) | 8 (5%) | |
| Service | | | | <.001 |
| Army | 378 (83%) | 254 (84%) | 124 (82%) | |
| Marine Corps | 44 (10%) | 38 (12%) | 6 (4%) | |
| Air Force | 23 (5%) | 7 (2%) | 16 (10%) | |
| Navy | 10 (2%) | 5 (2%) | 5 (3%) | |
| Civilian | 1 (<1%) | 0 (0%) | 1 (1%) | |
| Duty Status | | | | .12 |
| Active duty | 404 (89%) | 274 (90%) | 130 (86%) | |
| Reserve | 18 (4%) | 8 (3%) | 10 (6%) | |
| National Guard | 32 (7%) | 21 (7%) | 11 (7%) | |
| Other/Civilian* | 2 (<1%) | 1 (<1%) | 1 (1%) | |
| Military Rank | | | | .01 |
| E1-E6 | 377 (83%) | 259 (85%) | 118 (78%) | |
| E7-E9 | 42 (9%) | 29 (10%) | 13 (8%) | |
| Officer/Warrant Officer | 36 (8%) | 16 (5%) | 20 (13%) | |
| Civilian* | 1 (<1%) | 0 (0%) | 1 (1%) | |
| Military Occupational Specialty | | | | <.001 |
| Infantry | 173 (38%) | 142 (47%) | 31 (20%) | |
| Other/NR | 283 (62%) | 162 (53%) | 121 (80%) | |
| Mounted Status | | | | .001 |
| Mounted | 205 (45%) | 121 (40%) | 84 (55%) | |
| Dismounted | 242 (53%) | 178 (58%) | 64 (42%) | |
| Other/NR* | 9 (2%) | 5 (2%) | 4 (3%) | |
| Conflict at Time of Injury | | | | .19 |
| OIF | 273 (60%) | 179 (59%) | 94 (62%) | |
| OEF | 172 (38%) | 123 (40%) | 49 (32%) | |
| Other/Not Deployed* | 11 (2%) | 2 (1%) | 9 (6%) | |
| No. of Deployments | | | | .01 |
| 0 | 16 (4%) | 9 (3%) | 7 (5%) | |
| 1 | 139 (30%) | 88 (29%) | 51 (33%) | |
| 2 | 170 (37%) | 105 (34%) | 65 (43%) | |
| 3+ | 131 (29%) | 102 (34%) | 29 (19%) | |

NR indicates not recorded.
*Not included in $\chi^2$ analysis.

Table 2 shows the clinical characteristics of patients by blast exposure status. Compared to nonblast patients, greater percentages of blast-exposed patients reported a previous TBI, a history of unprotected noise exposure, tinnitus, and hyperacusis/noise sensitivity. A greater percentage of blast-exposed patients than nonblast patients reported routinely using the tactical communications system (TCS) as an HPD, while a greater percentage of nonblast patients than blast-exposed patients reported routinely using no HPD at all. A greater percentage of blast-exposed patients had developed an STS between their reference and subsequent audiograms than nonblast patients, but this difference was just shy of being statistically significant ($P$=.06) at the alpha level of 0.05. No statistically significant differences in nicotine use, PTSD diagnosis, sleep problems, and final disposition were found between blast-exposed and nonblast patients.

### Auditory Injury Outcomes

Of 456 patients in this study, 291 (64%) had developed an STS. Among the 304 blast-exposed patients, 203 (67%) had developed an STS, and among the 152 nonblast patients, 88 (58%) had developed an STS. Because not all patients had undergone an audiometric examination at each encounter captured in this study, the number of patients examined at each encounter is fewer than the cohort total of 456. Among the 432 patients with a predeployment audiogram, 115 (25% of the 456 cohort total) had already developed an STS compared to their reference audiograms.

Table 3 shows the incidence rates of STS per 1,000 person-years by blast exposure status, post-mTBI only, and age at time of mTBI. Blast-exposed patients developed

Table 2. Patient Clinical Characteristics by Blast Exposure Status.

| Characteristic | Total (%N) N=456 | Blast (%n) n=304 | Nonblast (%n) n=152 | *P* value |
|---|---|---|---|---|
| Previous Traumatic Brain Injury | | | | .04 |
| Yes | 153 (34%) | 112 (37%) | 41 (27%) | |
| No | 303 (66%) | 192 (63%) | 111 (73%) | |
| History of Unprotected Noise Exposure | | | | <.001 |
| Yes | 159 (35%) | 137 (45%) | 22 (14%) | |
| No | 258 (57%) | 137 (45%) | 121 (80%) | |
| NR* | 39 (8%) | 30 (10%) | 9 (6%) | |
| Hearing Protection Device Issued | | | | <.001 |
| TCS | 183 (40%) | 162 (53%) | 21 (14%) | |
| Earplugs | 15 (3%) | 13 (4%) | 2 (1%) | |
| Headset | 12 (3%) | 8 (3%) | 4 (3%) | |
| Other | 4 (1%) | 1 (<1%) | 3 (2%) | |
| None | 82 (18%) | 18 (6%) | 64 (42%) | |
| NR* | 160 (35%) | 102 (34%) | 58 (38%) | |
| Significant Threshold Shift | | | | .06 |
| Yes | 291 (64%) | 203 (67%) | 88 (58%) | |
| No | 165 (36%) | 101 (33%) | 64 (42%) | |
| Tinnitus | | | | <.001 |
| Yes | 242 (53%) | 181 (59%) | 61 (40%) | |
| No | 190 (42%) | 106 (35%) | 84 (55%) | |
| NR* | 24 (5%) | 17 (6%) | 7 (5%) | |
| Hyperacusis/Noise Sensitivity | | | | <.001 |
| Yes | 82 (18%) | 69 (23%) | 13 (8%) | |
| No | 362 (79%) | 227 (75%) | 135 (89%) | |
| NR* | 12 (3%) | 8 (2%) | 4 (3%) | |
| Nicotine Use | | | | .47 |
| Yes | 189 (41%) | 129 (42%) | 60 (39%) | |
| No | 257 (56%) | 167 (55%) | 90 (59%) | |
| NR* | 10 (2%) | 8 (3%) | 2 (1%) | |
| Posttraumatic Stress Disorder | | | | .46 |
| Yes | 323 (71%) | 218 (72%) | 105 (69%) | |
| No | 130 (28%) | 83 (27%) | 47 (31%) | |
| NR* | 3 (1%) | 3 (1%) | 0 (0%) | |
| Sleep Problems | | | | .78 |
| Yes | 384 (84%) | 255 (84%) | 129 (85%) | |
| No | 66 (14%) | 45 (15%) | 21 (14%) | |
| NR* | 6 (1%) | 4 (1%) | 2 (1%) | |
| Final Disposition | | | | .84 |
| Separation | 232 (51%) | 153 (50%) | 79 (52%) | |
| Return to Duty | 95 (21%) | 61 (20%) | 34 (22%) | |
| Rehabilitation | 81 (18%) | 56 (18%) | 25 (16%) | |
| Retired | 41 (9%) | 29 (10%) | 12 (8%) | |
| Other/NR* | 7 (1%) | 5 (2%) | 2 (1%) | |

NR indicates not recorded.
TCS indicates tactical communications system
*Not included in $\chi^2$ analysis.

an STS at a higher rate (115.5 cases per 1,000 person-years) than nonblast patients (92.8 cases per 1,000 person-years), in a blast-to-nonblast rate ratio of 1.24. After excluding the 115 patients who had already developed an STS on their predeployment audiograms compared to their reference audiograms, leaving the reference and postinjury (LRMC, postdeployment, and last) audiograms of the remaining 341 patients in the analysis, blast-exposed patients still developed an STS post-injury at a higher rate (94.0 cases per 1,000 person-years) than nonblast patients (75.8 cases per 1,000 person-years), in a blast-to-nonblast rate ratio of 1.24. When stratifying by age at the time of mTBI, blast patients aged 18 to 22 years developed an STS at the highest rate (238.7 cases per 1,000 person-years).

Analysis of the associations between STS or tinnitus and selected patient characteristics showed that only infantry (crude RR=1.21, 95% CI 1.06-1.39) and unprotected noise exposure (crude RR=1.27, 95% CI 1.11-1.46) were significantly associated with STS in the bivariate analysis. When adjusting for covariates using multiple logistic regression, these 2 variables entered the logistic regression model as statistically significant covariates associated with STS. Patients who served in the infantry were 54% more likely to develop an STS than patients who did not (adjusted OR=1.54, 95% CI 1.00-2.38), and patients who reported a history of unprotected noise exposure were 75% more likely to develop an STS than patients who did not (adjusted OR=1.75, 95% CI 1.12-2.75).

Blast-exposure status, Marine Corps service, an infantry MOS, PTSD diagnosis, unprotected noise exposure, TCS use, hyperacusis/noise sensitivity, and zolpidem (eg, Edluar, Zolpimist, Intermezzo, Ambien) use were each significantly associated with tinnitus in the bivariate analysis. On the other hand, patients aged 34 to 59 years and black patients were significantly less likely to develop tinnitus when compared to their respective reference groups (patients aged 18 to 22 and white patients, respectively). However, when adjusting for covariates using multiple logistic regression, only Marine Corps service, PTSD diagnosis, unprotected noise exposure, and zolpidem use entered the logistic regression model as statistically significant covariates associated with tinnitus. Patients who served in the Marine Corps were 7 times more likely to develop tinnitus than the reference group of patients who served in the Army (adjusted OR=7.05, 95% CI 2.65-18.76). Patients who reported a PTSD diagnosis were 66% more likely to develop tinnitus than patients who did not (adjusted OR=1.66, 95% CI 1.05-2.61). Patients who reported a history of unprotected noise exposure were 2.5 times more likely to develop tinnitus than patients who did not (adjusted OR=2.51, 95% CI 1.62-3.91), and those who reported zolpidem use were twice as likely to develop tinnitus than patients who did not (adjusted OR=1.97, 95% CI 1.12-3.48).

## Comment

This study was designed to characterize the incidence of hearing loss and tinnitus with respect to blast exposure in a cohort of US military personnel diagnosed with deployment-related mTBI. Differences in the demographic and clinical characteristics of personnel who were at greater risk of developing either auditory injury outcome (ie, STS or tinnitus) were found. Our findings indicate that in this cohort, blast exposure was significantly associated with younger age, males, Marine Corps service, junior enlisted rank, infantry, dismounted status at the time of injury, and greater numbers of deployments. Blast exposure was also significantly associated with previous TBI, unprotected noise exposure, tinnitus, and hyperacusis/noise sensitivity. However, our findings indicate that blast exposure was not significantly associated with hearing loss (although the association of $P$=.06 was just short of being statistically significant at the alpha level of 0.05), but unprotected noise exposure was associated with hearing loss. Blast exposure was significantly associated with tinnitus, but not when adjusted for other demographic and clinical covariates, whereas unprotected noise exposure was associated with tinnitus.

### Auditory Injury Outcome: STS

This study found an elevated incidence of hearing loss among blast-exposed mTBI patients compared to nonblast mTBI patients, consistent with the previous studies.[14,30] Over the surveyed career span (person-time at risk for developing hearing loss) blast-exposed mTBI patients developed hearing loss at a 24% higher rate than nonblast mTBI patients. This differential incidence was highest among patients aged 18 to 22 years, the youngest quartile of patients in this study. Blast-exposed patients in this age group developed hearing loss at a 41% higher rate than nonblast patients in this age group. Similarly, Dougherty et al reported blast-exposed service members who received a head injury were 32% (adjusted OR=1.32, 95% CI, 1.06-1.65) more likely to develop a hearing loss than service members without a head injury.[31] The difference in increased risk ratios between the current study and the Dougherty et al study may stem from different population samples and sizes. The Dougherty et al study did not include nonblast head injuries, and mTBI information was not captured. Additionally, the sampled population (n=4,817) was that of US service members who served in OIF and were both blast-exposed and received ear injuries.[31]

Results from the current study identified a STS in 25% of the total population at the surveyed predeployment audiogram or the last audiogram measured prior to injury. This may be due in part to the fact that a reported 66% of the total cohort reported being deployed 2 or more times prior to the current mTBI diagnosis. Previous reports have indicated that both deployment and combat experience increase a service member's likelihood of hearing loss.[28,29] It is likely possible that over half of the surveyed cohort may have had an STS (ie, hearing loss) that could be tied to military service and/or deployment prior to the current mTBI diagnosis. Rather than labeling a hearing loss by degree (mild, moderate, etc) alone, identifying an STS will capture those individuals whose hearing is functionally "within normal limits," and measureable damage to the auditory system is evidenced by a significant decrease in hearing sensitivity. Audiologic tests such as otoacoustic emissions and acoustic reflex thresholds have been shown to be abnormal in the presence of normal hearing in mTBI patients.[4,41] Therefore, these tests should be considered for inclusion in the audiologic test battery of patients presenting with mTBI.

Blast injuries can result in acoustic trauma either in isolation or in the presence of a head injury. Head injuries have previously been shown to be a risk factor for hearing loss. Lew et al reported an average 10 dBHL difference between blast-exposed and nonblast TBIs, with the more significant hearing loss occurring within the blast-exposed TBI group.[15] The current study defined hearing loss as an identified STS rather than a measured audiometric threshold (ie, dBHL level) among a population of service members with diagnosed mTBI. Results indicate, although not statistically significant, that mTBI caused by blast exposure increased the likelihood of a service member developing an STS by 15% (RR=1.15, 95% CI 0.99-1.35). Acoustic trauma, and subsequent hearing loss, which

Table 3. Incidence rates of STS per 1,000 person years by blast exposure status, post-mTBI only, and age at time of mTBI.

| Diagnosed STS | Blast (B) | | | Nonblast (NB) | | | Rate ratio (B/NB) |
|---|---|---|---|---|---|---|---|
| | n | Total person-years at risk | Rate per 1,000 person-years | n | Total person-years at risk | Rate per 1,000 person-years | |
| All (N=291) | 203 | 1,757.5 | 115.5 | 88 | 948.1 | 92.8 | 1.24 |
| Post-mTBI Only | 126 | 1,340.5 | 94.0 | 50 | 659.5 | 75.8 | 1.24 |
| Age (years) | | | | | | | |
| 18-22 | 64 | 268.1 | 238.7 | 12 | 70.8 | 169.4 | 1.41 |
| 23-26 | 51 | 291.2 | 175.2 | 21 | 119.2 | 176.2 | 0.99 |
| 27-33 | 49 | 488.5 | 100.3 | 26 | 300.0 | 86.7 | 1.16 |
| 34-59 | 39 | 695.6 | 56.1 | 29 | 458.1 | 63.3 | 0.89 |

can result from blast exposure to events such as IEDs or VBIEDs, have been found to cause permanent and large threshold shifts above 8000 Hz.[32] The DOEHRS audiometric testing typically does not exceed 6000 Hz, however 8000 Hz is an optional test frequency. This is an observed limitation of the current study as our analysis does not exceed 6000 Hz.

One such study which reviewed noise-induced hearing injuries (NIHI) by diagnosis codes during OIF in active duty US service members[35] noted both age and gender effects within the study cohort. Men had 15% to 78% greater rates of diagnoses than women. The risk ratio analysis in this study revealed, although not statistically significant, a gender effect with men at a greater risk for both STS and tinnitus. However, generalization is limited, as gender groups are not equal with 91% of the total sample population identified as male. Bivariate analyses of gender differences between MOI groups indicate a statistically significant difference between those blast-exposed and nonblast head injuries. Similarly, infantry or combat arms MOSs were reported to have higher rates of NIHI than other MOSs. This supports our finding that an infantry MOS increases one's likelihood of developing an STS by 54% (adjusted OR=1.54, 95% CI 1.00-2.38) compared to all other surveyed MOSs, which is statistically significant at the alpha level of 0.05.

### Auditory Injury Outcome: Tinnitus and Hyperacusis

The current study found a prevalence of approximately 53% of reported tinnitus in at least one ear in mTBI patients, with a prevalence of 59% of the blast-exposed cohort and 40% of those patients with a nonblast mTBI. The overall prevalence of tinnitus in the current study differs from the prevalence rate of 75% reported by Oleksiak et al.[8] This discrepancy may be due to either a smaller sample size compared to our study (37 of 75 Veterans who completed an audiologic assessment) and/or the referral criteria (Veterans who had both mTBI and newly identified hearing loss).

Results of the current study indicate that blast exposure increased the likelihood of self-reporting of and a diagnosis of tinnitus in at least one ear by 50% compared to those service members who were diagnosed with a nonblast mTBI (crude RR=1.50, 95% CI 1.21-1.85). This was statistically significant at the alpha 0.05 level. Shah et al found blast-exposed patients with TBI are 2.5 times more likely to have tinnitus postinjury than those patients who have nonblast TBIs.[14] Similarly, those service members diagnosed with deployment-related TBI were found to be 2.7 times more likely to report tinnitus after deployment than those without a TBI.[42]

Results from the current study indicate a number of factors that would indicate a protective effect against tinnitus. One such factor is age. The current study found service members aged 34 to 59 years were 22% less likely to have tinnitus than the 18 to 22 year old service members (crude RR=0.78, 95% CI 0.61-1.00), *P*=.05. Helfer et al reported that service members over the age of 40 years were 3 to 5 times more likely to seek audiologic evaluation and receive a NIHI diagnosis than those aged 17 to 19 years during the surveyed time period, with 29.1% of the sampled population receiving a diagnoses of tinnitus (unspecified or subjective).[35] This might coincide with a number of factors including evaluations prior to separation from service, delayed onset of hearing loss, and NIHI covering diagnoses other than hearing loss (tinnitus, TM perforation, etc).

Yet another factor that revealed a reduced risk for developing tinnitus was race/ethnicity. The current study found that among service members who report their race/ethnicity as white, black, or Hispanic, only those service members who identified as black were at a reduced risk of developing tinnitus by 31% (crude RR=0.69, 95% CI 0.51-0.95), *P*=.05. Similarly, Shargorodsky et al reported participants who report their race/ethnicity as black, non-Hispanic, and Hispanic had lower risk of any tinnitus than white, non-Hispanic participants by 38% (OR=0.62, 95% CI, 0.55-0.69) and 30% (OR=0.70, 95% CI, 0.61-0.80), respectively. Further, participants who report their race/ethnicity as black, non-Hispanic, and Hispanic were found to be at lower risk for frequent tinnitus than white, non-Hispanic participants by 59% (OR=0.41, 95% CI, 0.31-0.54) and 38% (OR=0.62, 95% CI, 0.50-0.77), respectively.[43]

Hyperacusis, or sensitivity to certain sounds and loudness levels, can occur as a result of blast-exposure. Examination of auditory injuries following blast exposure within civilian studies reveal an incidence rate for hyperacusis or sound distortion of 30% immediately following exposure.[44] Additionally, PTSD can exacerbate sound-tolerance issues, as one study found significant differences in sound-tolerance discomfort in Veterans diagnosed with PTSD and tinnitus compared to Veterans with tinnitus only.[45] The current study revealed 18% (n=82) of the total population having been either diagnosed with hyperacusis or noise sensitivity. However, when the rates were stratified by MOI, it was revealed that 23% of patients who were blast-exposed were diagnosed with either hyperacusis or noise sensitivity compared to 8% of patients who were not exposed. Bivariate analysis revealed a statistically significant increase of risk of tinnitus of 34% (crude RR=1.34, 95%

CI=1.13-1.59) among patients who self-report hyperacusis or noise sensitivity.

### Unprotected Noise Exposure/HPD Use

Bivariate analysis of HPD used with respect to hearing loss and tinnitus appeared to show an elevated risk (rather than a protective effect) of developing either auditory injury outcome when using the TCS. This may not accurately reflect the effectiveness of the TCS as an HPD, but may instead be an artifact of self-reporting by the patients in this study. "Type of Personal Hearing Protection Used" recorded on DD 2216 (line 15g) is inadequate to evaluate as a risk factor with respect to hearing loss and tinnitus, since it records "type of hearing protection that is routinely used by individual," not whether the individual was wearing hearing protection at the time of injury/acoustic trauma. Self-reported history of unprotected noise exposure may be a more accurate proxy for estimating routine compliance with hearing protection (or the lack thereof), since it appears to be a consistently robust risk factor predicting the elevated risk of both hearing loss and tinnitus in both the crude and adjusted risk analyses in this study. Similarly, Wells et al reported an increased odds of 18% for developing a hearing loss in service members whose MOS required the use of an HPD.[29]

Individuals engaged in combat and military operations rely on communication and hearing abilities to facilitate both teamwork and mission success. Hearing protective devices can often be a barrier to these efforts which may influence the actual use of the HPD by the service member. Previous studies have reported the difficulty experienced wearing and using HPDs during combat operations.[29,46] This may be due to a perceived diminished ability to: communicate with fellow team members; detect, perceive, and understand auditory messages, warnings, and/or commands; detect enemy threats; use and operate radio or intercom units; supervise ground troops not using radio communications; and/or maintain situational awareness including sound localization.[47-49]

### Other Factors

Auditory damage and subsequent hearing loss can be due to military activity such as noise exposure, blast exposure injuries, and ototoxic medications, either in isolation or combination, resulting in a synergistic effect.[30] This study attempted to analyze the use of prescription and over-the-counter medications by study subjects to determine if such use was associated with hearing loss and/or tinnitus, especially those that are known to be ototoxic. Of the 71 medications documented in LRMC medical records as being used by patients in this study, only the use of zolpidem, a prescription sleep aid, was associated with a two-fold increased risk of tinnitus. Most of these medications were used by too few patients in this study to have sufficient statistical power to show any differences in hearing loss and/or tinnitus between users and nonusers. Greater numbers of patients using a given medication under study are therefore needed to determine its ototoxicity in future pharmacoepidemiologic studies.

Previous studies have reported that mTBI is typically associated with higher rates of PTSD.[34,50] This study found 71% of the total population cohort (323 of 456 patients), or 72% of the blast-exposed and 69% of the nonblast patient groups, with a concurrent diagnosis of PTSD. Multivariate analysis revealed that the risk of developing tinnitus increased by 66% (adjusted OR=1.66, 95% CI 1.05-2.61) among mTBI patients with documented PTSD. Similarly, MacGregor, Dougherty, Tang, and Galarneau report statistically significant associations between tinnitus and mTBI (OR=1.63, 95% CI 1.10-2.41) after adjusted for PTSD, depression, age, combat blast mechanism, combat exposure, and Injury Severity Score.[34] Additionally, both PTSD and depression are associated comorbid diagnoses with mTBI, affecting up to 40% of cases.[51] While no identifiable association between the 2 diagnoses has been reported,[42] there is overwhelmingly more evidence in support of an association between PTSD and tinnitus than not.[45]

The current study found, although not statistically significant, that nicotine use increased the relative risk of acquiring an STS by 4% (crude RR=1.04, 95% CI 0.91-1.20), compared to nonsmokers. The identified association in the current study is consistent with literature in identifying a positive relationship between use of nicotine and hearing loss, with reports of current smokers being at an increased risk of 1.2 to 1.7 times.[29,52,53] A previous study reports current smokers were 54% more likely (age-adjusted OR=1.54, 95% CI 1.31-1.81) while former smokers were 30% more likely (age-adjusted OR=1.30, 95% CI 1.16-1.46) to report any tinnitus compared to those who never smoked.[43] This supports our finding, which, although not significant, reveals those service members who were diagnosed with mTBI and reported nicotine use were 17% (crude RR=1.17, 95% CI 0.99-1.39) more likely to also report and be diagnosed with tinnitus in at least one ear.

We recognize that our study is limited by a number of factors. The DOEHRS system does not regularly test above 6000 Hz in either ear. Therefore, this information is not available within our cohort. A future study should be executed with focus on the effect of TBI and MOI on hearing thresholds within the high and ultra-high

frequency range (ie, above 6000 Hz). Additionally, we are limited by the data set. Not all patient files had recorded audiograms at each of the five surveyed points in time.

## Conclusions

Interest in hearing loss and tinnitus within this population is driven by and becomes even more significant when combined with the fact that tinnitus and hearing loss are respectively the number 1 and 2 service-connected disabilities across the US armed forces. A number of factors would suggest that the total number of service members and combat Veterans with service-connected hearing loss and/or tinnitus is only to increase over time. Unlike other common military- and/or combat-related injuries, hearing loss is likely to progress with age.[30] Additionally, both acoustic trauma and/or blast exposure have been tied to delayed-onset hearing loss. The current clinical recommendation is that those exposed should receive long-term audiologic monitoring.[3,14,32] The findings from this study revealed no statistically significant difference in likelihood of developing a STS between MOI groups. This may suggest that experienced communication difficulties may lie in higher ordered structures beyond the peripheral auditory system and may not be captured with a standard audiometric threshold examination.

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This study was approved by the Brooke Army Medical Center Institutional Review Board and US Army Medical Research and Materiel Command Office of Research Protection, and each participant signed informed consent.

We do not plan to inform participants of the publication of this study.

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# Going GLP: Conducting Toxicology Studies in Compliance with Good Laboratory Practices

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## Abstract

Good laboratory practice standards are US federal regulations enacted as part of the Federal Insecticide, Fungicide, and Rodenticide Act (40 CFR Part 160), the Toxic Substance Control Act (40 CFR Part 792), and the Good Laboratory Practice for Nonclinical Laboratory Studies (21 CFR Part 58) to support protection of public health in the areas of pesticides, chemicals, and drug investigations in response to allegations of inaccurate data acquisition. Essentially, good laboratory practices (GLPs) are a system of management controls for nonclinical research studies involving animals to ensure the uniformity, consistency, reliability, reproducibility, quality, and integrity of data collected as part of chemical (including pharmaceuticals) tests, from in vitro through acute to chronic toxicity tests. The GLPs were established in the United States in 1978 as a result of the Industrial Bio-Test Laboratory scandal which led to congressional hearings and actions to prevent fraudulent data reporting and collection. Although the establishment of infrastructure for GLPs compliance is labor-intensive and time-consuming, achievement and maintenance of GLP compliance ensures the accuracy of the data collected from each study, which is critical for defending results, advancing science, and protecting human and animal health. This article describes how and why those in the US Army Medical Department responsible for protecting the public health of US Army and other military personnel made the policy decision to have its toxicology laboratory achieve complete compliance with GLP standards, the first such among US Army laboratories. The challenges faced and how they were overcome are detailed.

## History of Good Laboratory Practices

New Zealand introduced good laboratory practice (GLP) standards in 1972 as the Testing Laboratory Registration Act, which addressed record keeping, animal handling, dosing and observation procedures, equipment use, and facilities. Denmark passed a law the same year to promote GLPs. In 1975, Senator Edward Kennedy and representatives of the Food and Drug Administration (FDA) accused certain research laboratories in the United States of serious inadequacies in the execution and documentation of preclinical research studies. G. D. Searle and Company and Hazelton Laboratories were identified as having poor record keeping, inadequate data storage, and poor test facility management; performing inadequate personnel training; and committing fraud.[1]

The FDA published final GLP regulations (21 CFR 58) in December 1978, directing compliance by June 1979. However, a number of investigations were discovering serious problems before that regulatory mandate became effective. The scope of the problem reached the front pages of newspapers in 1981 when 4 executives of Industrial Bio-Test Laboratories (IBT) were indicted for providing false data to chemical companies, who in turn had presented that data to the US government to demonstrate their products were safe for market.[2] The findings were alarming because IBT submitted data on 200 pesticides, of which over 66% were judged invalid and only 19% acceptable. At that time, IBT operated the largest facility of its kind and performed more than one-third of all toxicology testing in the United States. In addition, IBT was accused of presenting results to chemical manufacturers that could not be verified. Newspaper editorials reported high rodent mortality and appalling husbandry conditions that offended public sensitivities and confounded research results.[3,4] The discoveries resulted in congressional hearings. The revelations led to reforms, amendments, and clarifications in the regulation of pesticides in the United States and Canada. Three of the IBT executives were convicted and sentenced in 1983.[5]

In January 1986, G. D. Searle scientists submitted a document entitled Good Laboratory Practice to the FDA and the Pharmaceutical Research and Manufacturers Association of America. Later that year, the FDA released proposed regulations on GLPs based on that Searle submission and published them in the *Federal Register*. In September 1987, the FDA published the Final Rule – Compliance Program Bioresearch Monitoring: Good Laboratory Practices, which incorporated the requirement for a quality assurance (QA) department,

the requirement for protocol preparation (ie, a study plan), characterization of test and control materials, and the requirement to retain specimens and samples.[1] Robinson succinctly describes the significance of this regulatory milestone:

> Within 14 years, therefore, GLP moved from an ad hoc concept to legally enforceable code, designed to control and regulate the quality of laboratory-based operations.[1]

The Environmental Protection Agency (EPA) encountered similar problems with data it received, and issued its draft GLP regulations in 1979 and 1980. The EPA published the Final Rules in 1983 in 2 parts, 40 CFR 160 and 40 CFR 792, which describe GLPs for conducting studies relating to health effects, environmental effects, and chemical fate testing. Additionally, the Organization for Economic Cooperation and Development (OECD) issued Principles of GLP in 1992, which disseminated information regarding the principles and their importance to many countries.

Carson and Dent[6] summarized the key events in the chronology of the implementation of GLP:

1972 New Zealand Testing Laboratory Registration Act

1972 Denmark National Testing Board Act

1976 US-FDA GLP Proposed Rule

1978 US-FDA GLP Final Rule

1979 OECD Expert Group on GLP

1979 US-EPA GLP Proposed Rule, Toxic Substances Control Act (TSCA)

1980 US-EPA GLP Proposed Rule, Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)

1983 US-EPA GLP Final Rules (TSCA and FIFRA)

1987 FDA Final Rule—Compliance Program Bioresearch Monitoring: Good Laboratory Practices

Concurrent with the publication of the final regulation, the FDA created 606 new positions to monitor biological research and began a pilot inspection program to determine baseline skill levels. Major findings in the industry included lack of QA departments, failure to test every batch of manufactured product, and failure to maintain standard operating procedures (SOPs).[1]

In the year 2000, the FDA issued *Toxicological Principles for the Safety Assessment of Food Ingredients*: *Redbook 2000*,[7] with chapters on general guidelines for designing and conducting toxicity studies, including GLP, test animals (and housing), test substances, experimental design, observations and clinical tests, necropsy, and microscopic examination. Currently, GLPs are also mandatory to ensure quality and integrity of data submitted under the TSCA (40 CFR Part 792) and FIFRA (40 CFR Part 160).

## Purpose of GLPs

To address and eliminate the concerns expressed in the 1970s regarding the credibility of toxicity testing, use of GLPs creates a clearly traceable audit trail from the individual animal data (or petri dish) to the official "raw data," to the initial report, and then to submission of the final report to EPA or FDA. Compliance with GLPs means ensuring adequately qualified personnel, adequate equipment, a single qualified study director for each study, a quality assurance unit, adequate test system and animal care facilities, well characterized test articles, and suitably managed archives of specimens and records. The overarching purpose of GLP compliance, therefore, is safety and the protection of public health.

## The Initiative for GLP Compliance in the Army Public Health Organization

In 1979, the FDA issued Guidance for Industry which established the requirement for GLP adherence for data generation to be used in an application for FDA approval. An initial GLP inspection was conducted of the Army Environmental Hygiene Agency (AEHA) in 1981, at which time deficiencies were noted. In September 1990, the AEHA submitted a report of acute skin, eye and photochemical irritation to a DoD customer. Unbeknownst to the AEHA, the customer submitted that report to the FDA as part of a therapeutic substance approval request. One month later, the customer informed AEHA that the FDA had observed that the report format was inconsistent with GLP regulations and then had decided to inspect AEHA facilities with regard to the conduct of that study. In November 1990, the FDA inspected and issued a report in June 1991 identifying 19 deficiencies involving receipt and disbursal logs, characterization of the purity of test article, incomplete raw data, inadequate control animals, and more. The report included a task to describe corrective action taken and planned, including a timeline for completion. The AEHA acted immediately, and the FDA was satisfied with the corrections executed or planned. From that point forward, the AEHA senior leadership invested time and resources to become fully GLP-compliant, and issued policy mandating such from the Toxicology Division.

The AHEA Chief of Staff in 1991 held quality science and quality deliverables among his highest priorities. In September of that year, he initiated a quality management system for the AHEA Toxicology Division to take

all measures necessary to establish the infrastructure to maintain compliance with GLP standards. This was deemed necessary because data from some studies performed by the Division are submitted to the EPA as part of applications for product approval. The EPA and FDA only approve compounds whose safety data are generated under GLP-compliant conditions.

As early as October 1991, principal investigators and other personnel attended GLP training and conducted an in-house gap analysis with special assistance by a GLP consultant. They identified specific needs for the organization, considering SOPs already in place, whether they were adequate, which new SOPs were needed, and what management controls were necessary to ensure compliance. Personnel from other divisions with an aptitude for quality assurance were reassigned into a nascent Quality Assurance Unit (QAU). In April 1992, the Toxicology Division was inspected by an outside consultant for compliance with the EPA GLP under the FIFRA. Additionally, the consultant provided training for personnel. Those personnel, in turn, wrote policy memoranda and drafted, evaluated, and established an internal audit program to perform regular self-assessments with "teeth" to ensure corrective actions would be taken when appropriate. In the past, auditors had occasionally spot-checked study conduct and compared methods used with approved animal use protocols, but such examinations were inadequate. With the new QAU, audits became much more stringent. Additional inspections in June 1992 and again 3 years later were performed to ensure AEHA was maintaining course.

The biggest challenge was to convince the staff of the value of the new requirements. Roughly 25% of the personnel recognized the need and supported it. Roughly 25% of personnel were unconvinced that the increase in administrative tasks would have any value in what they considered an already functional system of toxicity testing, and roughly 50% of personnel reserved judgment until they could see for themselves whether it was worth the effort. It required a change in culture, which was facilitated by the mandate from senior leadership.

It took 12 to 18 months to establish most of the policies, SOPs, and the audit system. Credentialed GLP trainers annually trained Toxicology Division personnel. Additionally, the QAU team sought additional training to augment their expertise with the standards to ensure that SOPs were adequately written and the laboratories under their purview were compliant.

From the initial reassignment of duties in September 1991 to the present, the QAU has grown to 20 personnel who monitor the GLP compliance of today's Army Public Health Center (APHC)* Toxicology Directorate (TOX) and oversee quality control for the Laboratory Sciences Directorate, Radiation Safety, Animal Care staff, Human Protection, and the Institute Animal Care and Use Committee (IACUC). The degree of "buy in" by affected personnel influences the amount of time it takes to successfully comply with GLP. Not every organization will need a multifunction QAU as is presently operating at the APHC. The mission will dictate the extent of quality assurance investment necessary.

At APHC-TOX, we routinely use GLPs for toxicity testing of all chemicals, whether or not they fall under the purview of the EPA. Provisions of the TSCA, FIFRA, and FDA regulations are met to produce data that can be submitted at a later date, if required. The last time EPA inspectors visited APHC was for a study of a mess kit cleaning compound, trichloromelamine, known officially as a field food service disinfectant. A 14-day range-finding study and a 90-day subchronic study in rats revealed oral toxicity of the substance when ingested. The organization was in full compliance with EPA requirements. Currently, GLP compliance is a way of life in the Toxicology Directorate. Training of SOPs is ongoing and formal GLP training is conducted annually, coordinated with another DoD facility that itself is moving toward compliance.

## Pros And Cons of "Going GLP"

The disadvantages of implementing GLP standards lead to the benefits of such action. The adoption of GLP regulations require training to produce adequately qualified personnel (documented as such), adequate facilities (verified by inspection), a single qualified study director for each study (identified by signature on an official protocol approved by the IACUC), and a QA unit specifically tasked with ensuring compliance with all relevant SOPs. Test system facilities must be verified by QA personnel, test articles or items must be adequately characterized, and documents that confirm such characterization maintained. Equipment used during the course of a study must be shown to perform as required, may require calibration (and documentation of such calibration retained), and be adequately inspected, cleaned, and maintained, all with documentation. The SOPs must be drafted by subject matter experts, approved by management (not QA), used to train personnel and to properly document preventive maintenance of test systems. Every

*The Army Environmental Hygiene Agency was redesignated as the US Army Center for Health Promotion and Preventive Medicine (USACHPPM) on August 2, 1994. On October 1, 2009, USACHPPM assumed additional responsibilites and was redesignated as the US Army Public Health Command, which was subsequently redesignated as the US Army Public Health Center on October 1, 2016.

study is driven by a study protocol/plan with specified content approved by the study director, and every study is concluded with a comprehensive study report with specified content. The disadvantages, therefore, are all the work involved and the meticulous documentation of that completed work. The resulting benefits are the documentation of achievements, well trained personnel, and a smooth-running, efficient organization that more consistently produces a high-quality product. To document training of personnel on SOPs and to revise SOPs, the APHC QAU uses, and therefore TOX uses, a MasterControl software package (MasterControl, Inc, Salt Lake City, UT). It was selected because it not only tracks SOP revisions and training, but provides other capabilities as well, such as supply functions, accident/injury reports, audit reports, and study protocols.

The GLP regulations require documentation of any laboratory worksheets, records, memoranda, notes, or exact copies of such documents that result from original observations and activities of a nonclinical laboratory study, and are necessary for the reconstruction and evaluation of the report of that study. Also required is an archive for orderly storage and expedient retrieval of all raw data, documentation, protocols/plans, and specimens generated as the result of a nonclinical laboratory study. One exception is the pathologist's working notes, including a working spreadsheet, are not considered raw data and are not subject to auditing. Only the signed, completed pathology reports (and processed tissues) are considered raw data subject to audit.[8] This is because of the judgment involved in assigning severity scores to lesions, which frequently entails more than one viewing of the slides, both unblinded and then blinded, to confirm.

It is obviously good scientific practice to ensure a laboratory maintains properly functioning equipment, qualified personnel, and properly recorded data. Facilities around the world, including developing countries, have demonstrated the capability to successfully perform GLP compliant studies. Some argue, however, these meticulous practices are too painstaking in research that is not being submitted to a regulatory agency. Others claim that since studies that do not meet these standards may be published in peer reviewed scientific journals, good science may be performed without GLP compliance. It is also accurate to state that compliance with GLP does not assure good science. Since good and bad science may be performed in GLP compliant or noncompliant fashion, this argument misdirects the discussion from the reason why GLPs are required: to ensure the accuracy of the data collected. Early discovery, animal model development, or other research in which methods may require frequent adjustment might not fit the GLP model. Data and reports of nonclinical safety studies, however, are used to make public health decisions; therefore, these studies must be meticulously conducted and recorded to ensure transparency, that is, they can be reconstructed from the records to demonstrate the integrity of the data. The nature of the test article determines the regulating agency and, therefore, the applicable GLP regulations. The FDA is responsible for protecting and promoting public health through the regulation and supervision of food safety, tobacco products, over-the-counter pharmaceutical drugs (medications), vaccines, biopharmaceuticals, blood transfusions, medical devices, electromagnetic radiation emitting devices, cosmetics, animal foods and feed, and veterinary products. Under the TSCA, the EPA regulates all commercial chemicals and substances (such as lead, formaldehyde, asbestos, mercury, and polychlorinated biphenyls), and FIFRA requires it to regulate insecticides, fungicides, and rodenticides. As Robinson points out:

> GLP is not a luxury. It is a necessity for any professional laboratory wishing to gain and retain the respect of its employees, clients, [and] regulators….[1]

## GLP Compliance as a Lifestyle

How does an organization know when GLP compliance has been achieved? Although internal audit processes can certainly identify areas where a procedure "misses the mark" and recommend corrective action, it is ultimately the FDA or EPA inspectors who have the answers for a given study.

How is GLP compliance maintained? The organization continues to follow the SOPs and policies put in place to achieve GLP compliance, with continuous monitoring by QA personnel, and continuous training and process improvement. Each individual engaged in the conduct of or responsibility for the supervision of a study shall have the education, training, and experience necessary to perform the assigned functions.[9] Thus, training is at the heart of GLP.

It is important to note that in the United States, GLP compliance is ascertained per study. An organization itself cannot be certified as GLP-compliant as is done in Europe. As illustrated in the Figure, good laboratory practices are comparable in the United States and other nations, but are not identical.

Going GLP can actually improve efficiency in performing a mission. Currently, the Division of Toxicologic Pathology of the Toxicology Directorate, which performs statistical analysis on all data, transfers spreadsheets of histologic data to a biostatistician in another directorate who performs Fisher's Exact test on the data using

|  | FDA | UNITED STATES ENVIRONMENTAL PROTECTION AGENCY | OECD |
|---|---|---|---|
| Conduct of a Study in Accordance with the Protocol | 58.130<br>(a) The nonclinical laboratory study shall be conducted in accordance with the protocol. | 792.130<br>(a) The study shall be conducted in accordance with the protocol. | Section II 8.3.2.<br>The study should be conducted in accordance with the study plan. |
| Test System Conformity with the Protocol | 58.130<br>(b) The test systems shall be monitored in conformity with the protocol. | 792.130<br>(b) The test systems shall be monitored in conformity with the protocol. | |
| Labeling of Specimens | 58.130<br>(c) Specimens shall be identified by test system, study, nature, and date of collection. This information shall be located on the specimen container or shall accompany the specimen in a manner that precludes error in the recording and storage of data. | 792.130<br>(c) Specimens shall be identified by test system, study, nature, and date of collection. This information shall be located on the specimen container or shall accompany the specimen in a manner that precludes error in the recording and storage of data. | Section II 8.3.1.<br>A unique identification should be given to each study. All items concerning this study should carry this identification. Specimens from the study should be identified to confirm their origin. Such identification should enable traceability, as appropriate for the specimen and study. |
| Availability of Gross Findings to Pathologists | 58.103<br>(d) Records of gross findings for a specimen from postmortem observations should be available to a pathologist when examining that specimen histopathologically. | 792.130<br>(d) In animal studies where histopathology is required, records of gross findings for a specimen from postmortem observations shall be available to a pathologist when examining that specimen histopathologically. | |
| Manual Recording of Data | 58.130<br>(e) All data generated during the conduct of a nonclinical laboratory study, except those that are generated by automated data collection systems, shall be recorded directly, promptly, and legibly in ink. All data entries shall be dated on the date of entry and signed or initialed by the person entering the data. | 792.130<br>(e) All data generated during the conduct of a study, except those that are generated by automated data collection systems, shall be recorded directly, promptly, and legibly in ink. All data entries shall be dated on the day of entry and signed or initialed by the person entering the data. | Section II 8.3.3.<br>All data generated during the conduct of the study should be recorded directly, promptly, accurately, and legibly by the individual entering the data. These entries should be signed or initialled and dated. |
| Changes to Mannually Recorded Data | 58.130<br>(e) Any change in entries shall be made so as not to obscure the original entry, shall indicate the reason for such change, and shall be dated and signed or identified at the time of the change. | 792.130<br>(e) Any change in entries shall be made so as not to obscure the original entry, shall indicate the reason for such change, and shall be dated and signed or identified at the time of the change. | Section II 8.3.4.<br>Any change in the raw data should be made so as not to obscure the previous entry, should indicate the reason for change and should be dated and signed or initialled by the individual making the change. |
| Automated Recording of Data | 58.130<br>(e) In automated data collection systems, the individual responsible for direct data input shall be identified at the time of data input. | 792.130<br>(e) In automated data collection systems, the individual responsible for direct data input shall be identified at the time of data input. | Section II 8.3.5.<br>Data generated as a direct computer input should be identified at the time of data input by the individual(s) responsible for direct data entries. |
| Changes to Data Recorded by Automated Systems | 58.130<br>(e) Any change in automated data entries shall be made so as not to obscure the original entry, shall indicate the reason for change, shall be dated, and the responsible individual shall be identified. | 792.130<br>(e) Any change in automated data entries shall be made so as not to obscure the original entry, shall indicate the reason for change, shall be dated, and the responsible individual shall be identified. | Section II 8.3.5.<br>Computerised system design should always provide for the retention of full audit trails to show all changes to the data without obscuring the original data. It should be possible to associate all changes to data with the persons having made those changes, for example, by use of timed and dated (electronic) signatures. Reason for changes should be given. |

Comparison of GLP Requirements for FDA, EPA and OECD. Adapted from FDA comparison chart.[10]

statistical packages to deliver to the pathologist incidence tables of findings and resultant *P* values. The data going to the statistician and the tables returning from the statistician pass through the QAU auditor to ensure data integrity. The demands in labor and time on the auditor and on the statistician can add 4-6 weeks to the production time of a large pathology report. Purchase of a pathology data management software package that is fully GLP-compliant meets the requirements for consistency and transparency, and reduces the time required for statistical analysis of the histologic data. In 2015, an increase in the number and complexity of toxicity studies, new personnel, and new software capabilities on the market (eg, a standalone pathology module) drove a re-examination of the feasibility of such a purchase. Market research is being done thoroughly, inviting key local players who can ask the most important questions. Purchase of a software solution will significantly enhance GLP-compliance and efficiency of pathology support to the toxicology mission.

An organization that decides to go GLP may not need a policy statement. What may be essential, however, is steadfast leadership to change the corporate culture, codify the decision, prevent digression, and prioritize the investment of resources. Leadership should ensure the benefits are kept ahead of forces against change. Milestones should be identified and rewarded when reached, and leadership should embrace training, assessment, data integrity, and commitment to continuous improvement as essential in providing useful products to ensure the health of the force and to maintain readiness.

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# An Expression of Change: Breastfeeding in the Military

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## Scenario

A junior US Army nurse attending the Basic Officer Leadership Course (BOLC) comes into the office of a US Army Baylor Graduate School professor that is near the main auditorium where her BOLC courses are being taught. She explains to the professor that she needs to express herself. The professor, open to an academic discussion with anyone, indicates to the junior officer that she can express herself anywhere in the building, especially in such an academic environment as the Army's Academy of Health Sciences. In response, the young nurse teaches the professor a lesson he will never forget. First, her comment about expression refers to the expression of breast milk. Second, she tells the professor there is no place available for her to express except the washroom, which is neither an appropriate nor healthy option. The professor allows the junior officer to use his office in private.

The above scenario is an actual event experienced by author J. Topinka. Today, 4 years later, there is a lactation room only several yards from where the junior officer approached that professor. In addition, in February 2016, the Defense Health Headquarters (DHHQ) published (internal) information on "DHHQ Lactation Support" and the 3 lactation rooms that provide private, clean spaces for nursing mothers and their babies. The rooms have a refrigerator for storing breast milk, a handwashing sink, pump cleaning supplies, comfortable chairs, and resource information. Volunteers have even provided blankets, pillows, white noise machines, privacy screens, resource materials, and other supplies.

While there has obviously been a great deal of change in breastfeeding policy since March 2010 when the Patient Protection and Affordable Care Act (PPACA), Pub L No. 111-148 was signed into law, how does current policy and the law apply to female service members at a time when they are taking on more and more responsibilities and duties within the military? This article endeavors to answer that question and provide military and medical leaders, as well as clinicians, guidance on how to deal with the needs of nursing service members and address outstanding issues that will undoubtedly be debated in the future.

## The Fundamentals

### Constitutional Right?

Even before state or federal laws supported breastfeeding, courts throughout the country made an effort to protect nursing mothers. One federal case, *Dike v School Board of Orange County Florida,* 650 F2d 783 (5th Cir 1981), exemplifies these efforts. In *Dike*, a kindergarten teacher, Janice Dike, breastfed her baby in a private, locked room at her school until the school's principal informed her that the practice violated a regulation. She tried to pump, but her baby refused the breast milk from a bottle. She then tried to get permission to breastfeed off the school campus but was refused. After the district court dismissed the case, she appealed to the 5th Circuit Court. While the Circuit Court held that "…her interest in nurturing her child by breastfeeding is entitled in some circumstances to constitutional protection against state infringement," the aftermath of the decision did not go in Janice Dike's favor when the case went back to the trial court.

### State Laws

Prior to 2010, there were, surprisingly, no federal laws that gave legal protection to mothers who wanted to breastfeed or pump for their babies. On the other hand, state laws on breastfeeding have existed in some form or another since 1995. In their 2011 article,[1] Murtagh and Moulton provided a solid analysis of state laws on breastfeeding. While these state laws may not have had much effect on the rules and regulations of the military prior to 2010, they were in effect in cities and communities where service members lived and shopped, thereby influencing military personnel and their families.

According to Murtagh and Moulton,[1] 23 states and 2 territories had enacted breastfeeding statutes by 2009 that, for the most part, focused on 3 main areas: break times, private locations, and workplace breastfeeding friendliness. Twenty-one of those state laws concentrated on

breastfeeding break times, with 19 on private locations. Eight prohibited breastfeeding related discrimination in the workplace, and three encourage "infant friendly" or "mother friendly" workplaces.

A current, very detailed list of state laws on breastfeeding can be found on the National Council of State Legislatures website (http:/ncsl.org). A review of this list shows that some states allow public breastfeeding. Unfortunately, many do not have any enforcement mechanisms such as penalties for violating the rights of nursing mothers. In addition, a careful review reveals that only a few states specifically state that breastfeeding is not indecent conduct. Unfortunately, in those states without such a provision, a nursing mother could theoretically be subject to prosecution.

In short, the states vary in their legal handling of breastfeeding, and that variance should at least be considered by members of the military who are assigned within those jurisdictions and who live in communities outside of a military reservation. While state breastfeeding laws can certainly influence the rules and regulations of military facilities, those facilities ultimately fall under federal control and the federal, jurisdictional authority of the commanding officer of that installation.

### Federal Laws

The PPACA was significant in the evolution of breastfeeding laws. As seen below, Section 4207 of the Act, which amended the Fair Labor Standards Act of 1938, codified at 29 USC 4207, gave working nursing mothers significant rights:

(r) Reasonable break time for nursing mothers

(1) An employer shall provide

(a) a reasonable break time for an employee to express breast milk for her nursing child for 1 year after the child's birth each time such employee has need to express the milk; and

(b) a place, other than a bathroom, that is shielded from view and free from intrusion from coworkers and the public, which may be used by an employee to express breast milk.

(2) An employer shall not be required to compensate an employee receiving reasonable break time under paragraph (1) for any work time spent for such purpose.

(3) An employer that employs less than 50 employees shall not be subject to the requirements of this subsection, if such requirements would impose an undue hardship by causing the employer significant difficulty or expense when considered in relation to the size, financial resources, nature, or structure of the employer's business.

(4) Nothing in this subsection shall preempt a State law that provides greater protections to employees than the protections provided for under this subsection.

Murtagh and Moulton note in their article that the law is significant for 2 reasons, and we agree. First, the law will most likely promote better public health by improving nursing mothers' ability to express milk. Second, in using the Fair Labor Standards Act, Congress made breastfeeding an "integral part of the nation's labor laws." We also believe that the law clarifies the minimal requirements of a private area to express breast milk and a reasonable break time to express breast milk that cannot be denied by anyone, anywhere, in any jurisdiction, state or federal. Technically, however, the law only applies to employees who are covered by the act's overtime provisions under 29 USC 213 (generally nonexecutive, hourly employees). Finally, we think that the last section of the law could yield discussions in the future should a state law be more protective of a nursing mother's rights.

In addition to Section 4207, we find it interesting that there is not much written on Pub L No. 108-109, Section 629, Division F, Title VI, which was passed on January 23, 2004 and now codified at 41 CFR Chptr 102-74-426, titled "May a woman breastfeed her child in a Federal building or on Federal property?" According to the language from the CFR noted below, the answer is yes:

> Public Law 108-199, Section 629, Division F, Title VI (January 23, 2004), provides that a woman may breastfeed her child at any location in a Federal building or on Federal property, if the woman and her child are otherwise authorized to be present at the location.

In states that do not include such provision in their laws, Pub L No. 108-109 could create conflict in federal facilities such as post offices and courthouses and on military reservations. Like many of the state laws that have such provisions for public breastfeeding, however, this law does not have any enforcement provision.

### US Military Service Policies

After the passage of the PPACA, author L. Turner wrote a small article regarding breastfeeding for the October 2010 issue of the US Army Medical Command's *Mercury*.[2] At the time, she and her associates believed that Section 4207 of the PPACA was just the beginning of change for the military in terms of breastfeeding policy. While the section had public health in mind, it was really an instrument of labor law and therefore may not technically apply to the military. However, we believe it was

an impetus to the policies that all the military services, including the US Coast Guard, have implemented.

Paragraph 4.15 of *Air Force Instruction 44-102*[3] addresses the use of a private, clean area for military expression and specifies that restrooms are not appropriate. Supervisors are encouraged to work with a nursing mother to ensure her work schedule allows 15-30 minutes every 3-4 hours to pump breast milk.

Section 15 of *Marine Corps Order 5000.12E*[4] notes that, at a minimum, the servicewoman should be afforded the availability of a clean, secluded space (not a toilet space) with ready access to a water source for the purpose of pumping breast milk. Command involvement is essential, and supervisors and nursing mothers will collaborate to keep to a minimum the amount of time required for milk expression.

Section 106 of *OPNAV Instruction 6000.1C*[5] stipulates that a commanding officer in the Navy shall ensure the availability of a private, clean room for expressing breast milk. There should be ready access to running water and refrigeration for safe storage of breast milk. The policy also addresses breastfeeding infants during duty hours on a case-by-case basis but granting such permission should not be a reason for granting excessive time for meals or from work. The Navy goes one step further through its *Bureau of Medicine and Surgery Instruction 6000.14A*[6] which provides guidance for Navy Medical Department personnel at Navy military treatment facilities. This is an excellent resource for clinicians and administrators, especially those in a joint environment.

*US Coast Guard Command Instruction 1000.9*[7] provides great detail in Section 7 concerning a lactation facility, storage, and lactation breaks. The policy is one of flexibility and support from the commanding officer. The policy, as with the Navy's, includes a case-by-case policy for requests for breastfeeding infants during duty hours.

*Army Directive 2015-43*[8] describes the US Army's policy for a space with access to a safe water supply, electricity, a flat surface, and a locking door. The space may not be a restroom. No time requirement for pumping is specified in the policy, but it does recommend 15 to 30 minute breaks 2 to 3 times a day. Like the Navy's Bureau of Medicine, the Army's Office of the Surgeon General and the US Army Medical Command issued *OTSG/MEDCOM Policy Memo 16-005*,[9] which provides comprehensive guidance to Army healthcare facilities on the implementation of breastfeeding policies. It is a great resource for medical leaders, especially those in a joint environment. The memo includes a sample work plan policy, a sample "Mother Friendly" Workplace Breastfeeding Schedule Request, and a sample infant feeding policy standard operating procedure.

### Military Leadership and Organizational Culture Implications

The scenario presented at the beginning of this article includes examples of leadership at an individual level, but has more broad implications of leadership relative to the organizational culture of each of the branches of the military. In this scenario, the professor demonstrated individual servant leadership by first serving the privacy needs of the junior officer. By putting her needs first, he removed barriers for the junior officer and also empowered her to commit not only to her family, but further commit to her branch of service and the public. He not only demonstrated individual leadership, but he distributed leadership by allowing the junior officer to meet the needs of her family and to meet the needs of her duties. Others have demonstrated positive correlation between associate engagement and loyalty to the organization and between work place policies supporting work life balance.[10,11] Leaders serving to support work life balance and empowerment increase associates' engagement and then subsequent loyalty to the organization.

Another inference can be drawn from the perspective of the leadership potential of the junior officer. Generally, mothers committed to the principle of breastfeeding have equal commitment to their workplace roles and a commitment to leadership. A commitment to breastfeeding parallels with high commitment to principled leadership. The professor further promoted the junior officer's commitment to her role and the community on behalf of the military and to her duties as an officer. From a perspective of executive leadership, a woman in a role of promoted leadership makes an intentional decision and commitment to do what is best for her family by committing to breastfeeding in conjunction with the demands of the organization. It is not always easy or convenient. She makes the conscious choice to lead in this way. Her commitment to her family and the health of the baby can also be extrapolated to how she commits to those whom she serves in her executive leadership role.

The professor in the scenario reinforced not only the junior officer's commitment to her family, but also supported one of the policy statements established by the American Academy of Pediatrics (AAP) on behalf of community leadership. The AAP has established a positive correlation of increased health benefits to both the infant and mother from breastfeeding. These health

benefits for the mother from the perspective of employment include decreased absenteeism related to infant illnesses; improved physical recovery after childbirth; decreased risk of chronic diseases such as rheumatoid arthritis, cardiovascular disease, and cancer; and decreased risk of postpartum depression, imputing an economic benefit to the United States of $13 billion per year.[12,13]

Contemporary leadership theories and best practices have originated from military leadership training and examples throughout history. The military branches have consistently modeled leadership in so many areas. In the Army's Strategic Vision,[14] the Army of 2025 and beyond will "leverage cross-cultural and regional experts" to conduct its operations across the globe. In this same Vision statement, the Army states that:

> ...it will consist of a balanced, versatile mix of scalable, expeditionary forces,…composed of agile and innovative institutions, solders, and civilians...with trusted professionals who strengthen the enduring bonds between the Army and the people it serves.

Versatility, balance, and innovation are all key concepts included in the Army's 2015 Vision of the Army in 2025 and beyond.

The Air Force Vision[15] states that it will be a "trusted and reliable joint partner with our sister services known for integrity in all of our activities…." In addition, the Air Force Vision states that those serving in the Air Force will "excel as stewards of all Air Force Resources."

Ray Mabus, US Secretary of the Navy, writes on behalf of the Navy's "Innovation Vision" that innovation includes changing the way that all personnel in the Navy think, challenging outdated assumptions, and removing bureaucratic processes that prevent great ideas from becoming reality."[16] With these formal vision statements seemingly embracing the concepts of agility and innovation for balanced workforce of professionals, does the military not have the opportunity to support agility, balance, innovation, and leadership in workplace culture with such policies as breaks for breastfeeding? One must ask; are the practices of not supporting "expression" counter to the professed Vision of the military branches? Organizational culture is only as consistent and stable as the behavioral and policy practices throughout.

## Unfinished Business

We believe that each branch of military service has made great strides in developing and implementing service policies for breastfeeding. In general, the policies mirror 29 USC 207(r)(1) in that they provide at least a reasonable break time for a service member to express break milk and they require some place other than a bathroom that is shielded from view and free from intrusion by coworkers and the public.

Some issues remain, however, which we think must eventually be addressed. First, we are aware that breastfeeding in public on federal property remains open for debate. The provision of 41 CFR Chptr 102-74-426 described earlier is, on its face, straightforward. But how does it apply on a military reservation where uniformity is key and professional appearance and good order and discipline are enforced? In one recent case, a US Army command had to withdraw a policy that required nursing mothers to nurse their infants "discreetly" and cover themselves. In another case, an Air Force commander rescinded his breastfeeding policy that required nursing mothers to leave the area if they refused to use a private room or a nursing cover. The authors do not have a magical solution except to say that command flexibility will be key, and a cultural modification may be necessary to fit within the parameters of the law.

Second, we wonder about the provision in 29 USC 207(r)(4) presented earlier that addresses more prescriptive protections resulting from future state laws. What if a particular state affords a nursing mother more rights than are afforded to her on the local military installation? Will an exception to policy be implemented for the installation so that its policies can be consistent with the laws of the local communities? What if the nursing service member works in leased office space? The hypotheticals are numerous, but they are worth discussing as an expression of change.

## Conclusion

Hopefully, this article will educate many and stimulate debate among others. Change is inevitable, especially when public health is at stake; and the law is often the avenue through which change is made. As David Suzuki wrote:

> A baby nursing at a mother's breast…is an undeniable affirmation of our rootedness in nature.[17]

The law and policy on breastfeeding will eventually catch up to nature, even in the military. With approximately 14% of the active-duty being women (15.3% of officers are women), the military has the opportunity to not only "catch up" to public health and policy recommendations, but also has the duty to lead in workplace practices honoring the history and culture of leadership as demonstrated in the past.[18,19]

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# Chemical Weapons Exposures in Iraq: Challenges of a Public Health Response a Decade Later

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ABSTRACT

An October 14, 2014 article in *The New York Times* reported that the US Department of Defense (DoD) concealed, for nearly a decade, circumstances surrounding service members' exposure to chemical warfare agents (CWA) while deployed to Iraq in support of Operations Iraqi Freedom and New Dawn from March 13, 2003, to December 31, 2011, and alleged failure of the DoD to provide expedient and adequate medical care. This report prompted the DoD to devise a public health investigation, with the Army Public Health Center (Provisional) as the lead agency to identify, evaluate, document, and track CWA casualties of the Iraq war. Further, the DoD revisited and revised clinical guidelines and health policies concerning CWA exposure based on current evidence-based guidelines and best practices.

On October 14, 2014, *The New York Times* published the first part of an in-depth exposé, "The Secret Casualties of Iraq's Abandoned Chemical Weapons,"[1] initiating a landslide reaction and innovative response by the Department of Defense (DoD). The article alleged that:

> From 2004 to 2011, American and American-trained Iraqi troops repeatedly encountered, and on at least six occasions were wounded by, chemical weapons remaining from years earlier in Saddam Hussein's rule.[1]

The investigation contained eyewitness accounts by 17 service members and 7 Iraqi police officers claiming exposure to aging chemical weapons abandoned years earlier, pointing out that the weapons were not part of an active arsenal during the Iraq war; they were remnants from Iraq's arms program in the 1980s during the Iran-Iraq war. *The New York Times* also asserted the US government, specifically the DoD, kept secret the fact that these troops were being injured as they stumbled across aged chemical weapons that Saddam Hussein had built for his war with Iran, stating that the "[American government]...failed to prepare its troops and medical corps for the aged weapons it did find." Further:

> The American government withheld word about its discoveries even from troops it sent into harm's way and from military doctors. The government's secrecy, victims and participants said, prevented troops in some of the war's most dangerous jobs from receiving proper medical care and official recognition of their wounds.

Perhaps most disappointing was the article's allegation that "[n]one of the veterans were enrolled in long-term health monitoring."

A US Army chemical warfare specialist examines potentially hazardous materiel discovered in an abandoned Iraqi chemical munitions factory, Camp Taji, Iraq, circa 2013. Photo courtesy of SSG Ryan Jacobsma, US Army.

A March 25, 2015 *New York Times* article, "Veterans Hurt by Chemical Weapons in Iraq Get Apology," reported an apology Under Secretary of the Army Brad Carson offered for the DoD mishandling of past cases.[2] As described in the article, the DoD acknowledged that

the military had not followed its own policies for caring for troops exposed to old and abandoned chemical munitions, and that the Pentagon had failed to follow-up thoroughly. The DoD Uniformed Services also agreed to consider awarding Purple Heart medals, which may be awarded for injuries requiring medical treatment that are a result of enemy action,[3] to those exposed to makeshift bombs made from chemical weapons. Mr Carson further stated, "My ambition, and what I am committed to, is to make sure that any person who was exposed to a weaponized chemical or a chemical weapon is addressed through this process." He explained that, under the new guidelines, Veterans identified as possibly having suffered exposure to a chemical weapon will be contacted by their respective military service branch, evaluated in a structured interview, and in some cases, invited for a full medical examination. The Veterans will also be provided with documentation of their exposure and have their medical records updated accordingly. This information, Mr Carson promised, will also be shared with the Department of Veterans Affairs (VA) to help Veterans receive follow-up care and/or submit claims.[2] Following the October 2014 *New York Times* article, DoD leadership formed a working group, under the direction of Under Secretary Carson, and developed an investigation centered on 4 objectives:

1. identify, contact, and evaluate service members and Veterans for possible exposure to chemical warfare agents (CWA);
2. offer and provide service members and Veterans with likely or confirmed CWA exposure a medical exam, if appropriate;
3. document these efforts in the Defense Occupational and Environmental Health Readiness System (DOEHRS) and individual service treatment records and ensure the VA is informed of these findings, and;
4. consider appropriate recognition for service members and Veterans with injuries resulting from likely or confirmed CWA exposure.[4]

The working group designated the Army Public Health Center (Provisional) (APHC(P)) as the DoD lead agency for the identification of service members potentially exposed to weaponized chemical agents through the concept of a public health investigation.

Further, the working group adopted a definition for CWAs derived from the Chemical Weapons Convention. As such, chemical exposures of concern included any toxic chemical listed on Schedule 1 or any toxic chemical when applied as a method of warfare (eg, incorporated into a munition or device specifically designed to cause death or other harm through the release of the toxic chemical during the employment of the munition or device).[5] Principally, this included, among other substances, nerve agents, mustard agents, and chlorine.

## Clinical Effects of Mustard

Sulfur mustard is a blister agent. Signs and symptoms of sulfur mustard exposure normally do not occur immediately thereafter.[6(pp204-212),7,8] Instead, they manifest 2 to 48 hours following exposure. The areas of involvement include exposed skin, eyes, and the respiratory tract, usually when it has vaporized due to temperature. Tender (or thin) skin, mucous membranes, and perspiration-covered skin are more sensitive to its effects. More severe exposure may involve the gastrointestinal tract, the central nervous system (CNS), and the hematologic system.[7] The extent of physiologic damage depends on the route and intensity of exposure. Effects from liquid mustard manifest sooner than effects from mustard gas. In mild to moderate cases, blisters occur 2 hours and up to 18 hours after the appearance of skin redness or erythema, which typically occurs 4 to 8 hours following exposure, but can occur one to 24 hours after exposure. The erythema may be accompanied by an itchy sensation (pruritis) and painful burning. The vesicles do not contain sulfur mustard and will not cause secondary contamination. In severe cases, vesication is more severe, followed by areas of necrosis. Systemic health effects include fever, malaise, prostration, and emesis. With ocular exposure, the onset of lacrimation, irritation, pruritis, burning, blepharospasm, and possible miosis occurs within 4 to 12 hours. With higher levels of exposures to the eye, onset of symptoms occurs within 3 to 6 hours. In addition to the above, there is increased erythema, eyelid edema, and moderate pain. With severe exposures, usually due to liquid mustard, the onset occurs within one to 2 hours. In addition to the above, increased eyelid edema, painful photophobia, cornea ulceration, severe pain, and blindness may occur.

Mild inhalation (respiratory) exposures will manifest within 2 to 24 hours with rhinorrhea, sneezing, epistaxis, hoarseness progressing to "toneless" voice, barking cough, anosmia, wheezing, and dyspnea in smokers and asthmatics, and, sometimes, nasal or sinus pain.[6(pp204-212)] More severe exposures manifest within 2 to 6 hours. In addition to the above, there is acute inflammation of the upper and lower airways, necrosis of the respiratory epithelium, possible obstruction of the upper and/or lower airways secondary to pseudomembranous formation, airway occlusion from inflamed and necrotic cells, and death secondary to pneumonia. Other organ systems may be affected by other routes or increased

severity of exposure.[7] The symptoms of ingestion exposure include nausea, emesis, abdominal pain, diarrhea, possible chemical burns of the gastrointestinal tract, and prostration. Acute CNS effects, such as CNS excitation and seizures, occur only following very severe exposure.[6(pp204-212)] In addition to being a vesicant, sulfur mustard is also an alkylating agent. Absorption into the body can injure the bone marrow, lymph nodes, and spleen, resulting in leukopenia and immunosuppression.

### Clinical Effects of Sarin

Signs and symptoms of sarin exposure usually occur within seconds to hours following a mild or moderate dose. Symptoms manifest within seconds to minutes after exposure to sarin gas while the onset of symptoms following exposure to liquid sarin may take up to 18 hours.[6(pp142-154)] An exposed individual can experience one or more of the following: rhinorrhea, blurred vision, lacrimation, miosis, eye pain, blurred vision, excessive salivation, cough, chest tightness, tachypnea, diarrhea, abdominal pain, nausea and/or emesis, polyuria, confusion, drowsiness, weakness, headache, bradycardia, tachycardia, muscle twitching, hyperhidrosis, hypotension, or hypertension.[6(pp142-154),7] Exposure to a large sarin dose may result in more deleterious health effects including loss of consciousness, paralysis, seizures, and respiratory failure, which may lead to death.[6(pp142-154),7,8]

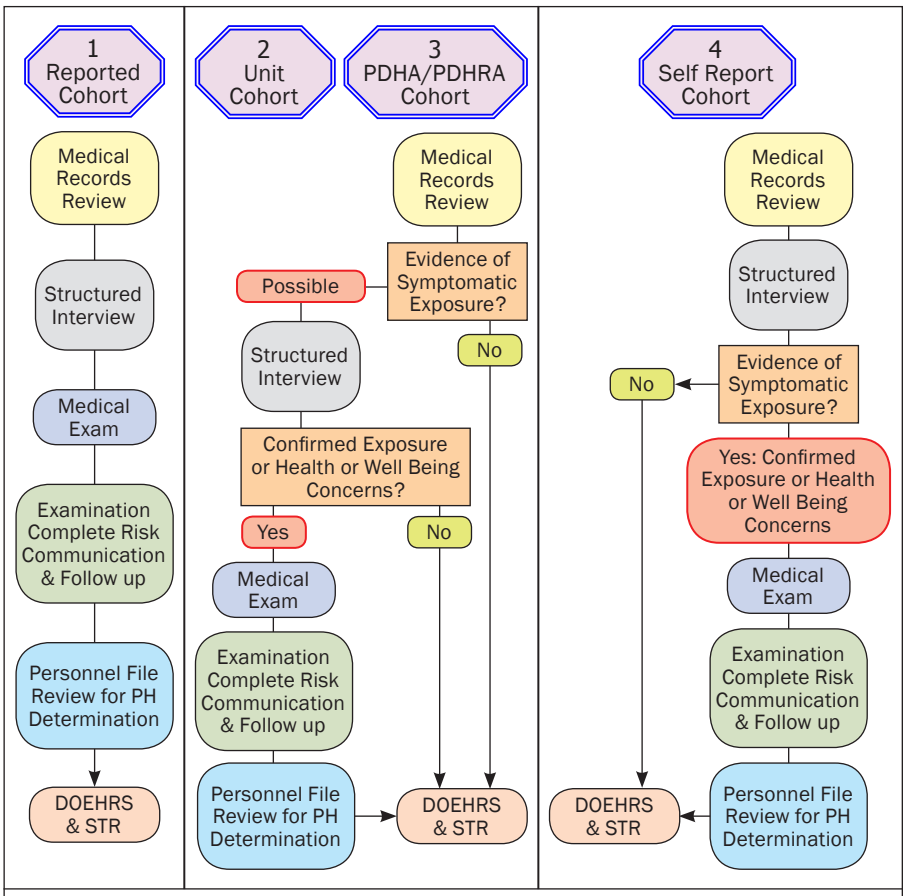
### Elements of the CWA Investigation

Current and former service members were assigned to one of 4 cohorts, depending on the methodology which led to their identification as having been exposed to CWAs.[4,9] The first cohort included those 26 service members and Veterans identified in the October 2014 *New York Times* article.[1] Seventeen Soldiers, 6 Marines, and 3 Navy personnel were identified as exposed through contact with old munitions. As APHC(P) gathered contact information and contacted these individuals, it was determined that efforts should be made to identify the units of service members and Veterans specifically identified in media reports, and assess whether other unit members were potentially exposed; the identified 244 potentially exposed personnel formed Cohort 2. Further, service members and Veterans identified upon review of Post-Deployment Health Assessments (PDHA) or Post-Deployment Health Re-Assessments (PDHRA) as having been exposed or potentially exposed to CWAs in Iraq during Operations Iraqi Freedom and New Dawn at any time after March 19, 2003, through December 31, 2011, were included as Cohort 3.[4,9,10] The PDHA/PDHRA forms are completed when service members redeploy and answer a series of questions about current health, changes in health, and deployment-related exposure concerns. The form has a question regarding potential exposure to chemical, biological, or nuclear agents as well as radiation. If this multipronged question is answered in the affirmative, the service member is supposed to elaborate, and the healthcare provider reviewing the form should discuss this with the service member. Unfortunately, details of the exposure or the discussion are not evident on the forms, so the forms for all redeployed service members during the time period were searched for key words and assessed for inclusion in Cohort 3. This cohort was expanded to include service members and Veterans identified in operational reports as having been exposed to weaponized toxic industrial chemicals (also considered CWA) at any time from March 19, 2003 through December 31, 2011.[9] Operational records regarding exposure incidents during this period remained classified and so use of this information for unclassified purposes required coordination between APHC(P) and US Central Command intelligence. The last cohort, Cohort 4, included service members and Veterans who self-reported exposure or potential exposure to CWAs while deployed to Iraq in support of Operations Iraqi Freedom and New Dawn at any time from March 19, 2003 through December 31, 2011.[4,9] Two weeks following the first *New York Times* article,[1] the DoD made a hotline available to individuals who wished to report CWA exposure. This was the Office of the Deputy Assistant Secretary of Defense for Force Health Protection and Readiness hotline (1-800-497-6261). Although this hotline existed prior to this investigation and receives calls on a number of topics, it was specifically publicized to Veterans and service members starting on October 31, 2014, to report CWA exposures.

The review process varied somewhat for the respective cohort populations as shown in the Figure. Once a service member or Veteran entered a cohort, the service treatment record was reviewed to determine if there was any documentation of symptomatic CWA exposure and/or treatment as well as sequelae or subsequent medical follow-up. A "positive" finding was a clinical encounter record entry for a CWA exposure or any indication of a personal CWA or possible personal CWA exposure, including the service member or Veteran endorsing or mentioning a personal CWA exposure in the absence of an AHLTA* clinical encounter record entry for a CWA exposure.[11] The service member or Veteran may have endorsed a history of personal CWA exposure in a follow-up visit, which may or may not have been related to a CWA exposure; yet, it is possible that there was not an associated initial clinical encounter for CWA exposure due to a lack of in-theater electronic health records early

*AHLTA is the DoD electronic health record system.

in the conflict. In this investigation, a review of a service member's or Veteran's AHLTA electronic health record is completed and documented in DOEHRS, a Military Health System (MHS) resource for entering, assessing, managing, and reporting occupational and environmental exposures.[10,12] Paper treatment records, including paper medical records from the deployment, were not available centrally and were not reviewed as part of this investigation. It is recognized that the electronic medical record might not contain all encounters, particularly those from early in the conflict before deployment use of electronic systems was in place.




The chemical warfare agent exposure review processes for the respective service member and Veteran population cohorts. DOEHRS indicates Defense Occupational and Environmental Health Readiness System; STR, service treatment record; PH, Purple Heart.

## Structured Interview

If the medical record screen contained evidence of a symptomatic exposure to a CWA, or for all hotline callers, the service member or Veteran was offered a structured interview (SI).[11] The voluntary SI is a tool used to confirm the service member's or Veteran's inclusion based on location, time, and possible exposure to CWA. Based on the results of the SI, the service member or Veteran may be offered a clinical assessment (CA) at a military treatment facility. Service members and Veterans may decline the SI and/or CA without any effect on their eligibility for military or Veteran's benefits.

The SI is a healthcare provider-conducted, telephonic interview that occurs after the medical records screening to formally evaluate a potential CWA exposure.[9,11] This interview does not establish a physician-patient relationship, but serves as a fact-finding effort to determine the probability of a confirmed or likely CWA exposure based on the service member's or Veteran's history of exposure, symptoms and the time until onset, and any available CWA testing results. A service member or Veteran was offered a medical examination if the interviewing provider determined that sufficient evidence existed to support a likely or confirmed CWA exposure. A service member or Veteran progressed to the end-point determination of "no evidence of symptomatic exposure" if the interviewing provider determined there was not a preponderance of evidence to support CWA exposure (eg, the likelihood of CWA exposure for the service member or Veteran was determined to be less than 50%). Pertinent service member or Veteran information from the SI was documented in DOEHRS and uploaded. If the interviewing provider determined that the service member or Veteran had no evidence of symptomatic CWA exposure, the necessary CWA exposure information was documented in DOEHRS. Clinical assessments were offered to any service member or Veteran who was determined to have a confirmed or likely exposure. Additionally, service members or Veterans who were considered to have no evidence of a symptomatic exposure may request and be granted an examination.[9]

## Clinical Assessments

The CAs were conducted at the Walter Reed National Military Medical Center (WRNMMC). In order for Veterans who were no longer DoD beneficiaries to be seen at WRNMMC, Secretarial Designee status was obtained. This status allowed invitational travel orders to be created for the Veteran to travel to WRNMMC and undergo a one-time examination to assess whether the Veteran had current signs or symptoms of known

health effects associated with CWA, including any referrals which the examining provider considered indicated, at no cost.[11] Lodging and per diem were included. The designee status did not include treatment or ongoing follow-up in the MHS. For this effort, APHC(P) provided administrative support to schedule SIs and CAs in coordination with WRNMMC, created invitational travel orders, and assisted service members and Veterans with travel arrangements and vouchers associated with the assessment. The WRNMMC Preventive Medicine Department, through the Occupational Medicine clinic providers, conducted the CAs and coordinated with other specialties as needed, documented the visit in the medical record, and provided health risk communication.

### Documenting the Investigation

As mentioned earlier, DOEHRS is an MHS resource for entering, assessing, managing, and reporting occupational and environmental exposures.[12] The Solution Delivery Division of Health Information Technology at the Defense Health Agency manages DOEHRS, which consists of multiple business areas: industrial hygiene, environmental health, radiation health, incident reporting, and registries. Useful for both garrison and deployed operations, it is mandated by various DoD policies and public laws and is an exposure system for AHLTA.[10,12] The existing incident reporting module was modified to meet the needs of the CWA initiative by allowing the creation of a record for each individual, attaching the medical record, the SI, the CA, and allowing the recording of status and key information throughout the process. This system also contains a mailbox function so that records can be forwarded to the appropriate individual when certain steps are completed, allowing traceability throughout the process. In addition, this system is a permanent archival system which can be accessed by the VA directly or through future DoD-VA information sharing platforms. Although the AHLTA record for each individual who undergoes a CA contains the information regarding the visit and the disposition, DOEHRS serves as a searchable system to retrieve CWA process information on all participants who have entered the process, regardless of the disposition, including demographic information, medical record screening results, the SI outcome, and the CA outcome.

### Recognition

The initial *New York Times* article[1] identified 14 Soldiers who, it was claimed, suffered from CWA exposure and were not appropriately recognized for their injuries. Information was gathered to determine whether or not these individuals were eligible for the Purple Heart award.[3] As part of this effort, individuals who were identified as having a confirmed or likely exposure to CWA were contacted to discuss possible concerns regarding awards. Such scenarios included exposure to CWA from the enemy use of an improvised explosive device. Exposure through digging up ordnance or contact with old leaking munitions is generally not considered to be enemy activity. The Army assisted Soldiers or Veterans who believe themselves to possibly be eligible for the Purple Heart award to identify and submit the appropriate documentation to support their request for consideration.[9]

### Communication: Keeping the Individual and DoD Leadership Informed

High-level interest in this process necessitated keeping leadership informed of the recommended approach, progress, and roadblocks. In the early phase of the process, daily briefings were conducted between APHC(P) and the Office of the Surgeon General to communicate changing cohort sizes, progress in identifying and contacting the individuals, as well as the status of draft correspondence to the cohort members, fact sheets, and the implementation plan.[9] Although APHC(P) was the lead agency on this effort and had the majority of the participants, the other military services also had potential exposures. Coordination between representatives from their respective Surgeons General and Manpower and Reserve Affairs was conducted in weekly briefings to Under Secretary Carson. During and between these briefings, recommendations and issues were discussed. The briefings occurred for months until the overall process, including the CA, was established, although the cohorts, particularly Cohort 4, might still grow. The first CAs occurred in February 2015, less than 4 months after the process was initiated.

### Conducting Interviews

The SI was a provider-service member or Veteran conversation designed to gather information from the service member or Veteran about their potential exposure to CWA. There were a variety of responses as providers spoke to these service members and Veterans. While some service members or Veterans were happy that the program was in place, some were angry that they had been told not to talk about the event, and others stated that medical personnel did not always recognize the exposure and proceed accordingly. For some, talking about the event and the deployment was traumatic and difficult; for others, it was cathartic and a relief to get it out in the open. Many expressed the opinion that the interview was worthwhile, as well as gratitude that "someone cares" and "someone believes them." It was necessary to provide the service member or Veteran with the time he/she needed to discuss their exposure scenario and concerns in their own way. In some cases, individuals had not previously shared this information

with a provider and did not know if they should be concerned about long-term health effects. To successfully conduct these interviews, it was essential to practice not only good and compassionate listening to establish trust and a connection to the service member or Veteran, but to allow them to express the variety of their feelings surrounding their exposure experiences.

### Long-term Follow-up

A key concern of the author of the initial *New York Times* article[1] was the lack of medical follow-up for affected service members; prior Army policy espoused lifetime monitoring. Although it was alleged that these exposures were kept "secret" and that medical providers were not made aware of the possibility of exposure, in 2004, the Army Medical Command (MEDCOM) published and widely disseminated guidance documents[13,14] prompted by 2 chemical agent exposure events. The first incident involved 2 service members exposed to a leaking munition containing nerve agent. The second incident involved the exposure of a US Air Force explosive ordnance technician to sulfur mustard in response to dredging a leaking World War I round from the bottom of the Atlantic Ocean. Each of these exposures was the subject of a medical case report.[15,16] The 2004 MEDCOM documents included guidance for the acute medical treatment of CWA exposure casualties (with focus on moderate to severe exposures), clinical and chain of command notification procedures, and exposure-related evaluation and follow-up plan.[13,14] Further, the guidance contained a broad follow-up protocol, which included surveillance of casualties extending beyond full clinical recovery due to the relative rarity of casualties suffering symptomatic CWA exposures. In light of casualty interviews and inconclusive or nonexistent medical documentation, the 26 service members initially identified by *The New York Times* were presumed to have not been clinically managed in accordance with the 2004 Army MEDCOM guidance for nerve agents and sulfur mustard. It should be noted that MEDCOM guidance is not theatre medical policy in a combatant command's area of responsibility, and at the time of exposure, the reporting of such casualties was classified and not easily accessible by typical MEDCOM queries. Service members with symptomatic CWA exposure in theatre may have been treated appropriately and followed-up on redeployment, but no centralized documentation was available.

The APHC(P) collaborated with representatives from the Army, Navy, Marine Corps, Air Force, Defense Health Agency, and VA, as well as academic experts and other nongovernmental personnel to review the scientific basis for the recommended long-term management of CWA casualties. The collaborative team specifically focused efforts on sarin and sulfur mustard by incorporating a review of published literature, best clinical practices, and information gleaned from exposure-based interviews and clinical examinations of CWA casualties. The literature review of military, medical, and scientific articles was conducted to research information and focused on information about the persistent health effects and the delayed-onset of signs and symptoms following exposure to chemical agents.[17-23] The review identified articles describing the use of CWAs during World War I, where the types of weapons employed ranged from tear gas and mustard gas to phosgene and chlorine. Also found during the review was the act of domestic terrorism perpetrated by members of Aum Shinrikyo in Matsumoto, Japan, who released sarin gas from several sites in the Kaichi Heights area during the evening of June 27 and morning of June 28, 1994. This event, known as the Matsumoto incident, resulted in the deaths of 8 people and injuries to over 200 others. It occurred about 9 months before the better known Subway Sarin Attack on March 20, 1995, an act of domestic terrorism perpetrated in Tokyo, Japan, by members of the same religious group who released sarin gas simultaneously from 5 containers on 3 different Tokyo subway lines. Information was also available relating to exposures during the Iran-Iraq War in which Iraq used large quantities of chemical weapons, reportedly mostly sarin and sulfur mustard, against both civilian and military populations in Iran.

The focus on the long-term medical management presupposed that the service member or Veteran underwent a clinical evaluation which determined that all acute and subacute health effects of the CWA exposure had resolved. The review report does not address those with high-level exposures, as these individuals often have life-long health issues and may need to remain under the care of specialists throughout their lives. To our knowledge, none of the exposures associated with the investigation fit that description. While the report presents some background and information about long-term health effects, its main purpose is to provide guidance on long-term follow-up of exposed individuals. Specific follow-up recommendations resulting from clinical evaluations should be discussed with the individual using principles of shared decision-making and should be documented in his/her medical record. All individuals who undergo evaluation for symptomatic CWA exposure(s) should be provided with educational materials. For this initiative, due to limitations in the ability to predict long-term health outcomes, individuals with confirmed symptomatic exposure(s) to CWAs will be sent a follow-up letter or health status questionnaire from APHC(P) on a periodic basis. The purpose of this periodic contact is threefold: (1) to provide patient

education and updates when new information becomes available; (2) to help ensure optimal treatment of identified health conditions; and (3) to reassure the patient and demonstrate continued commitment. The DoD will communicate with the VA as needed.

### Follow-up for Mustard Exposures

All individuals with ocular exposure to sulfur mustard should be educated about the importance of good eye hygiene and eye care (eg, avoiding putting anything in the eyes that was not designed specifically for that use, seeing an eye care professional regularly). If an individual required eight weeks or more of medical care at the time of exposure, they should also be educated about the possibility of recurrent keratopathy and should be encouraged to see an eye care professional immediately for any unexplained eye pain or visual changes.

All individuals with ocular exposure to sulfur mustard should be counseled to notify their eye care professional and other healthcare providers about their exposure history. Late-onset or late-occurring ocular effects (these are effects which were not present acutely or subacutely after the exposure) of sulfur mustard exposure are impossible to predict and are unlikely to be identified in a periodic evaluation. Fortunately, late-onset ocular effects are unlikely to occur based on the currently known level of exposure to US military personnel; therefore, no formal DoD or VA medical surveillance is recommended.

Individuals exposed to sulfur mustard by inhalation should be educated about the possibility of long-term pulmonary effects and the importance of avoiding pulmonary toxins, including tobacco smoke, second-hand smoke, etc. These individuals should be educated about the importance of establishing and maintaining a close ongoing relationship with a primary care provider, so that changes in their clinical status are more likely to be detected. All individuals with symptomatic inhalation exposure to sulfur mustard should be encouraged to report all cases of pulmonary symptoms and/or pulmonary diagnoses to their provider. Each encounter for pulmonary evaluation should be used as an opportunity to emphasize the importance of avoiding pulmonary toxins—most notably, tobacco smoke. Fortunately, there have been no documented cases of high-level exposures to sulfur mustard involving US service members in a combat zone since World War II.

All individuals with symptomatic dermal exposure to sulfur mustard should be educated about the possibility of long-term dermal effects and the importance of avoiding dermal injuries, including sun- and tanning booth-induced injuries to the affected skin. Individuals with symptomatic dermal exposure to sulfur mustard with residual scarring at the site(s) of exposure-related dermal burns should be educated about the possibility of cicatricial malignancies and the importance of seeing a skin care professional if the scar(s) begin(s) to change color, shape, texture, etc. All individuals with asymptomatic dermal exposure to sulfur mustard should be reassured regarding the absence of evidence of long-term effects in the absence of acute effects. They should also be educated about the importance of avoiding dermal trauma, including sun exposure and tanning booth injuries.

There is no clear scientific or medical evidence concerning any risk of late-onset skin effects. If such effects exist, they are likely to be uncommon. They are also unlikely to be identified in a regular periodic evaluation; therefore, no formal DoD or VA medical surveillance is recommended.

Based on the levels of exposure during exposure incidents involving US service members while deployed to combat zones since WWII, systemic effects of sulfur mustard exposures are unlikely to occur. Therefore, no formal DoD or VA medical surveillance is recommended.

### Follow-up of Nerve Agent Exposure

Signs and symptoms of nerve agent exposure can range from frank effects of cholinergic poisoning with high-level exposure (convulsions, near lethality, or requiring intervention to prevent death), to the presence of threshold cholinergic effects (miosis, rhinorrhea, measurable depression of cholinesterase) with intermediate exposures, to an absence of immediate clinical signs and symptoms with minimal exposure. If the eyes are exposed to vapor only, miosis may be the only sign. Currently, the literature does not support the development of late-onset symptoms in a nerve agent-exposed person after the acute effects of nerve agent exposure have resolved.

Although there have been no documented cases of high-level exposures to nerve agents involving US service members since development of these agents in the 1930s, individuals with high-level exposure to nerve agents should undergo comprehensive neurological evaluation (with consideration of neuropsychological, vestibular, and ophthalmologic testing and/or referrals) to determine if there are any residual effects from their exposures. This also applies to highly exposed individuals who are asymptomatic from the abnormalities identified at the time of their initial referral for specialty evaluation. This/these evaluation(s) should attempt to isolate

any residual nerve agent exposure effect from effects due to posttraumatic stress disorder (PTSD) and/or traumatic brain injury (TBI), which can be difficult. If this evaluation and concurrent testing are normal, or, if abnormal, explained by other factors such as PTSD or TBI, no further follow-up is recommended. If the above tests are abnormal and cannot be explained by a non-nerve agent-related condition or situation, it is recommended that the individual be referred to a neurologist, neuropsychologist, otolaryngologist, or ophthalmologist for further evaluation and follow-up as appropriate. Once these tests normalize, another cause for the abnormalities is identified, or the individual becomes asymptomatic with residual test abnormalities, no further follow-up is recommended.

All individuals with intermediate-level exposure to nerve agents (documented exposure that required treatment at the time) should undergo comprehensive neurologic evaluation (with consideration of neuropsychological and vestibular testing) to determine if there are any residual effects from their exposures. This applies whether or not they are symptomatic at the time of their initial referral for specialty evaluation. This evaluation should attempt to isolate any residual nerve agent exposure effects from effects due to PTSD and/or TBI. If this evaluation and concurrent testing are normal, or, if abnormal, explained by other factors, no further follow-up is recommended. If the above tests are abnormal and cannot be explained by a non-nerve agent-related condition or situation, it is recommended that the individual be referred to a neurologist, neuropsychologist, or otolaryngologist for further evaluation and follow-up as appropriate. Once these tests normalize, another cause for the abnormalities is identified, or the individual becomes asymptomatic with residual test abnormalities, no further follow-up is recommended.

All individuals with mild or low-level exposure to nerve agents should be educated regarding what is known about late-onset effects of nerve agent exposure, especially in cases of mild or no symptoms at the time of the exposure. Individuals with a history of possible exposure to nerve agent vapor only (with no possibility of liquid exposure) who had no signs of exposure within 15 minutes of the potential exposure can be considered non-exposed (because these effects occur within seconds to minutes after exposure). No follow-up is recommended.

## Conclusion

Since the onset of the public health investigation in October 2014 until the time of this writing (March 2015), over 7,504 service members and Veterans have been evaluated in this process. Cohort 1 ultimately contained 48, while Cohort 2 had 226, and 5,777 were identified via the PDHA forms plus an additional 103 identified in operational records brought Cohort 3 to a total of 5,880. There were 1,350 hotline callers comprising Cohort 4. A total of 7,474 medical record reviews were completed, and 1,152 SIs conducted. At the end of the process, 6,439 individuals were identified as having no evidence of a symptomatic exposure. Two hundred sixty-six individuals were categorized as confirmed or likely to have had a symptomatic exposure. Of these, 111 have completed the CA and 52 have declined it. An additional 52 individuals had no evidence of symptomatic exposure but requested an examination anyway. At the onset of the effort in October 2014, APHC(P) worked to identify the individuals in Cohort 1 and called them to discuss their exposures, signs, and symptoms at the time; the medical care that they had received; and their current health status. A decision was made that all members of Cohort 1 would be seen at WRNMMC. While this strategy incurred travel costs, the purpose of having all individuals evaluated at one location was to promote standardization. A previous surveillance program established for individuals who were exposed to a hazard at the Qarmat Ali Water Treatment Plant in Iraq[23] employed a limited number of medical treatment facilities to conduct the evaluations. This was to ensure the needed level of specialty care was available, and to limit providers to a few who understood the objectives of the examination and were comfortable with the risk communication aspects of the program. This had been successful and was the model of choice for the effort. The CA was designed after a review of the literature regarding acute as well as chronic exposures, but it was designed without knowledge of the actual level of exposure of those who would be evaluated.

As described earlier, the 4 goals of the process were to:

1. identify, contact, and evaluate service members and Veterans for potential CWA exposure;
2. offer and provide service members and Veterans with likely or confirmed CWA exposure a medical exam, if appropriate;
3. document these efforts in DOEHRS and individual service treatment records and ensure the VA is informed of these findings; and
4. consider appropriate recognition for service members and Veterans with injuries resulting from likely or confirmed CWA exposure (these were met (to date)).

Coordination with the VA to provide identifying information on participants has already occurred. A tremendous amount of effort was expended to process the 7,504

potentially exposed individuals to date, and the ratio of confirmed or likely to potentially exposed was small at 226/7,504, or 3.5%. In almost every case, the service member or Veteran had a usual source of care, and many of them were already being followed, for example, for their respiratory complaints. The assessment conducted was not a compensation examination for the VA, but served to document an exposure (although most often with no true measure of dose). In the future, should an individual develop a condition that they attribute to their past exposure, in the absence of a presumption, another examining physician will assess the probability of an association. These efforts to identify service members and Veterans who had likely or confirmed exposures to CWA while in theatre might have been avoided if there was a central registry of service members who had been determined through medical channels to have had such an exposure. This serves to illustrate the importance of field recognition, care, and reporting of symptomatic exposures, and of making this information available in an unclassified format. In most instances when signs and symptoms were typical, contact with the medical community ultimately occurred and these exposures were known outside of classified channels.[15,16] At present, DOEHRS has an incident-reporting module for this purpose. While some individuals may not have sought medical care, had there been a centralized, unclassified location to report these exposures, or had the postdeployment health assessments clearly identified them, it would have been possible to conduct active or passive surveillance. The question on the PDHA that addresses chemical exposures is rolled in with other exposures, making it difficult to search the forms for likely exposures. To the degree that reporting remains classified, there remain substantial barriers to identifying and following such exposures. Ideally, after being promptly recognized and treated in the field with concurrent electronic medical record documentation, personnel symptomatically exposed to CWA would redeploy and receive appropriate follow-up care from their next healthcare provider. Even then, however, there would be no ability to easily identify these individuals, should the need arise, apart from the use of a very specific reporting code. To prevent future difficulties, unique symptomatic exposures should be reported through unclassified channels in accordance with deployment policy and tracked when appropriate.[10]

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# Bridging the Gap Between Burn Pits and Waste-to-Energy Technology: Safe and Effective Waste Management in Contingency Operations

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Waste-to-energy (WTE) offers a partial solution at the convergence of 2 major Department of Defense (DoD) concerns: (1) addressing health effects due to burn pit emissions exposures and (2) reducing dependency on fossil fuels in contingency environments. Operating forces, combatant commands, and technology developers are excited about the prospect of using WTE as a solution, but a multitude of considerations and limitations must be integrated before it can be declared a success. Waste-to-energy systems may produce cost benefits and reduced environmental impact, but ancillary advantages such as a reduction in health related concerns can only be inferred from minimally available information and data. Accurate problem framing is the first, crucial step to developing successful military equipment that can be employed in austere conditions where US forces are deployed. To date, industry has been very successful in developing large scale WTE systems intended to handle municipal solid waste from civilian urban areas. However, such commercially available systems are not designed for harsh mobile deployment applications where burn pits have commonly been the expedient solution to solid waste disposal. The continuous presence of US forces in austere, deployed environments over the last decade has produced a growing concern over adverse health effects to service members from toxic burn pit emissions. These concerns have pushed alternate technologies, such as WTE, into the collective spotlight.

When operating far distances from established installations, the DoD employs base camps which vary in physical size and personnel in order to accomplish various missions. The exact base camp categories will be explained in more detail later, but generally the camps are categorized as "extra small," "small," "medium," and "large." Understanding the typical military waste streams at extra small and small base camps provides an awareness of the baseline of materials that require waste management treatment. This article synthesizes these components to create an understanding for the dynamic considerations that must be addressed to develop systems that could potentially create a more efficient, sustainable, and ultimately safer environment for US service members.

Understanding the current state of knowledge for burn pit risk is the first step in analyzing what emissions hazards from burning waste must be addressed by a WTE system. Knowledge gaps from limited burn pit emission sampling data in deployed environments have been partially addressed through simulated emissions testing.

Presented in this article are the required DoD critical performance parameters and characteristics for a WTE system that is a safe alternative to burn pits. Within environmental considerations, this analysis is primarily focused on managing nonhazardous solid waste, defined as "any material or substance [solid or liquid] that is inherently waste-like by being no longer suitable for its originally intended purpose"[1] In addition to narrowing the scope of environmental considerations to solid waste management practices, considerations will also be limited to bases with fewer than 2,000 personnel (of which extra small and small base camps are considered).[2]

## Human Health Risk from Open-Air Burn Pits

Concern over the health effects of burning solid waste during deployments in combat theaters has been voiced by service members, veterans, the media, Congress, and the President. It has been the subject of several joint DoD and Veterans Administration (VA) symposia, scholarly articles, a military medical textbook, congressional inquiries, and federal legislation.[3-9]

Waste disposal in contingency settings requires thoughtful consideration of waste stream segregation, safe disposal of hazardous materials, personnel safety, and the available disposal infrastructure, in addition to the technology to support incineration and landfills for other disposal options. During Operations Iraqi Freedom

(OIF) and Enduring Freedom (OEF), there was a notable absence of supporting infrastructure or contracting possibilities for field waste disposal. The only limited methods of field disposal were burial, incineration, or a combination of the two. At times, the sheer volume of waste required near continuous operation of burn pits at several locations, resulting in the constant production of smoke. When conducting an open burn of solid waste, siting of the burn area is critical to ensure that it is downwind from living quarters and camp populations. Burn pit smoke plume direction is dependent on weather conditions, and smoke can linger low to the ground during inversions.[10] Consequently, considerations such as the direction of prevailing winds and location of personnel billeting areas had to be continually assessed as use of open burning persisted.

As clearly illustrated in Figure 1, thick black smoke from open pit burning was often a visual cue accompanying odors, eye irritation, and/or cough. As the size and number of inhabitants increased at Joint Base Balad, Iraq, trash volume grew from 2 tons per day to several hundred. While incinerators were purchased relatively early in the base expansion of this specific example, contractual issues delayed their use, and in response, concerned preventive medicine personal conducted air sampling from January to April 2007. The sampling targeted expected burn pit emissions, including particulate matter (PM), volatile organics, metals, polycyclic aromatic hydrocarbons (PAH), and polychlorodibenzodioxins/furans. The sampling was conducted over multiple 24-hour periods at locations chosen to represent typical and maximum exposure levels for the general population. Additional sampling was conducted during different seasons. From the 163 samples collected, 4,811 individual analyte results were obtained and used in a quantitative screening human health risk assessment. The cancer risk estimated in this assessment was in the range considered to be "acceptable" under US Environmental Protection Agency (EPA) guidelines, but some volatile organic compounds were measured at levels that might be associated with acute irritation.[10,11] Limitations of the environmental sampling and risk assessment methodology include incomplete capture of the variability in waste streams and meteorological conditions over time, and the potential presence of toxicants that were not quantified.[5]

Dramatic photographs of burn pit smoke and accounts of the exact nature of items (plastic water bottles, soiled military uniforms, tires, etc) which had been burned (indicating indiscriminant burning) circulated on social media and generated further concern. Congress responded with language included in the National Defense Authorization Act for FY 2010 which identified items that were prohibited from uncontrolled burning, and limited the time period that a base commander could rely on open burning as the waste disposal method at base camps housing more than 100 personnel.[12] In 2011, the Institute of Medicine (IOM) assessed air sampling data, risk assessment information, and relevant epidemiological data and concluded that there was insufficient evidence to draw firm conclusions regarding long-term health risks associated with burn pit exposure.[7] The IOM committee noted that monitoring data "omitted some of the pollutants considered criteria pollutants in the United States such as sulfur dioxide, ozone, nitrogen dioxide, ozone, nitrogen dioxide, and carbon monoxide." They also stated that it was likely that additional pollutants were present as "the burning of household waste is known to emit other pollutants," but were simply not measured due to time or budget constraints. The IOM determined that health effects (particularly respiratory) from burn pit emissions exposures are plausible, due primarily to PM, but that burn pits were likely only one of

Figure 1. Smoke from open air burn pits, Joint Base Balad, Iraq, in 2006. Photo courtesy of CPT Scott Newkirk, USA.

many sources contributing to ambient PM levels. The literature reviewed during the study provided limited but suggestive evidence of decreased pulmonary function (but not disease) associated with combustion products.

Continued, active stakeholder engagement with Congress resulted in the Dignified Burial and Other Veterans' Benefits Improvements Act of 2012 which was signed into law on January 10, 2013.[4] The law required the VA to establish a voluntary registry for veterans who had deployed to locations near open burn pits. The registry was subsequently expanded to include all deployment-related airborne hazards (to address hazard sources beyond burn pits) and named the database the "Airborne Hazards and Open Burn Pit Registry" (AHOBPR). In August 2013, DoD committed to include active duty service members in the AHOBPR. Open burning of trash may be only one of many contributors to service members' health risk, but it has been viewed by many as a risk fully under DoD control and thus unacceptable as a continued standard operating procedure. To date, over 59,000 service members and Veterans have enrolled in the AHOBPR registry, and the IOM is reviewing the information in order to determine how to best utilize the self-reported data.

Respiratory conditions are the most plausible and most studied consequence of exposure to burn pit emissions. Geographically, personnel deployed to Southwest Asia are also exposed to other respiratory hazards, including fine dust, emissions from vehicles, generators, weaponry, and local industry. The DoD conducted environmental sampling to characterize these exposures, focusing on ambient PM, a hazard which routinely exceeds health guidelines in the region.[13,14] The studies evaluating associations between deployment and respiratory health indicate a range of different and occasionally contradictory findings, including: (*a*) no evidence of an association between deployment and chronic respiratory conditions[15,16]; (*b*) an association between specific respiratory diseases and deployment[6,17,18]; and (*c*) evidence of increased respiratory symptoms but not a specific diagnosed disease.[19-22] Although these studies have methodological limitations that constrain the strength of the conclusions that can reasonably be drawn from them, their findings warrant continued investigation.

Despite the interest in the health effects of burn pits, there have been few studies to specifically address health outcomes associated with them rather than those involving deployment as a variable. Newly reported chronic bronchitis or emphysema, newly reported asthma, and self-reported respiratory symptoms and possible burn pit exposure were examined among deployed Army and Air Force personnel surveyed in 2004-2006 and 2007-2008 (N=22,844). Increased symptom reporting was observed among Air Force personnel located within 2 miles of Joint Base Balad; however, this finding was marginally statistically significant. This study did not generally support an elevated risk for respiratory outcomes other than symptoms among personnel deployed within proximity of documented burn pits in Iraq.[9] Another retrospective cohort study was conducted among military personnel who, between January 2005 and June 2007, were deployed to either of 2 locations with burn pits in Iraq, or to either of 2 locations without burn pits in Kuwait.[6] Incidence rate ratios (IRRs) were estimated using 2 nondeployed reference groups. Rates among personnel deployed to burn pit locations were also compared directly to those among personnel deployed to locations without burn pits. Significantly elevated rates of encounters for respiratory symptoms (IRR=1.25; 95% CI: 1.20-1.30) and asthma (IRR = 1.54; 95% CI: 1.33-1.78) were observed among the formerly deployed personnel relative to personnel stationed in the United States. Personnel deployed to burn pit locations did not have significantly elevated rates for any of the outcomes relative to personnel deployed to locations without burn pits. These results are consistent with the hypothesis that OIF deployment is associated with subsequent risk of respiratory conditions. Elevated medical encounter rates were not uniquely associated with burn pits.

The IOM review of data on the burn pit registrants may stimulate research into other potentially related health outcomes, such as cancer, for example. If specific associations develop, it is a possibility that specific health outcomes could be presumptively linked to burn pits by the VA. Whether associations with health conditions emerge or not, continued open burning of large volumes of trash is perceived to be dangerous to service members' health, unnecessarily consume political goodwill with the host country, and are an unacceptable risk from a force protection standpoint.

## Simulating Emissions from Open-Air Burn Pits

Operational burn pits, such as those used at large scales during OIF and OEF, no longer exist for study. Therefore, simulating open air burn pit emissions is a critical tool to fill knowledge gaps for health and environmental effects. The challenge of simulated testing is twofold. First, the simulated waste must be reasonably representative of waste compositions observed across the range of waste characterization studies and waste input methods and composition should be uniform across various tests. Secondly, the emissions data collection methods should be uniform across tests, which allows for comparative analysis.

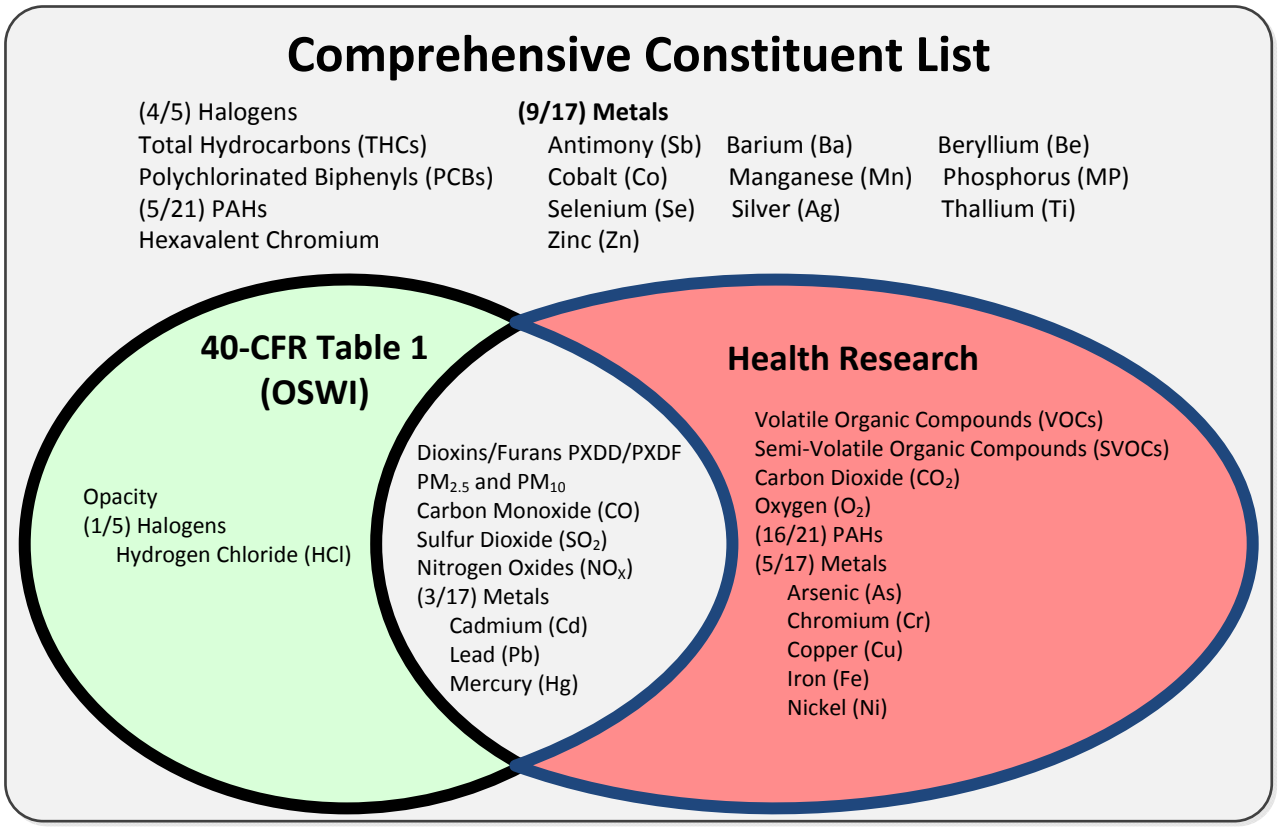


Figure 2. Comprehensive emissions constituent list. Data from Woodall et al,[23] Aurell et al,[24] and EPA.[25]

In 2012, two studies related to emissions from "military-waste" sought to gain better understandings of open pit burning in an appreciably controlled environment. The emissions analyses of both studies were comprehensive and both efforts researched similar emissions constituents for various burn conditions. One study analyzed simulated military waste at the EPA's Open Burn Test Facility (OBTF) to determine the effect on emissions when plastics were removed from the waste stream, namely plastic water bottles.[23] The emissions analysis included: polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), particulate matter ($PM_{10}$, $PM_{2.5}$), polychlorinated and polybrominated dioxins/furans (PCDD/F and PBDD/F), and criteria pollutants. The study concluded that targeted removal of plastics (such as water bottles) "has no apparent effect on reducing pollutants and may even result in increased production of PCDD/Fs and PBDD/Fs pollutants" due to reduced British thermal unit (BTU) content of the waste resulting in lower overall combustion temperatures.[23]

The second study compared emissions from 2 separate waste streams (municipal solid waste and US Army Depot waste) by way of 2 different disposal techniques (burn pits and an air curtain burner). The article studied, "a comprehensive array of emissions… including CO2, $PM_{2.5}$, volatile organic compounds (VOCs), polyaromatic hydrocarbons (PAHs), polychlorinated dibenzodioxins and -furans (PCDDs/PCDFs), polybrominated dibenzodioxins and -furans (PBDDs/PBDFs), and metals."[24] The results suggested that emissions from the air curtain burner were significantly lower for $PM_{2.5}$, VOCs, and PAH, and 50 times lower for PCDD/PCDF and PBDD/PBDF as compared to the open pit burning.[24] While this study was very informative, both disposal methods employed actual municipal solid waste and garrison waste with unknown variations of composition and consistency. A standardized waste stream that simulates military waste compositions would be beneficial for similar tests in the future. Moreover, a deliberately constructed and precisely controlled military waste standard would reduce uncertainty associated with varied waste streams and allow for more accurate comparison between studies.

## Open Burning Emissions of Interest

Common emissions of interests from burning waste can be drawn from the 2 studies mentioned above[23,24] and generally include PM, VOCs, PAHs, and PCDDs/PCDFs. However, to meet regulatory standards, a shorter bare-minimum emission testing list is available. Nonetheless, to meet academic research objectives, a

much longer list of testing is possible. Several factors and regulations must be considered to determine what emissions are critically important for analysis. The size and function of a system for waste management application at extra small and small base camps would classify the system as an other solid waste incineration (OSWI) unit under 40 CFR §60[25] for systems built after 2004. Table 1 to Subpart EEEE of 40 CFR §60 specifies 10 air pollutant concentration limitations for OSWI systems, presented in Figure 2. While relying on the regulations outlined in 40 CFR is appropriate for environmental regulations, it does little to inform researchers about the more than 180 emissions (http://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications) that are hazardous air pollutants and are toxic to human health. The US Army Research Laboratory provides an extensive list of possible emissions that can be tested according to EPA methods.[26] Previous tests on simulated burn pit emissions that focused on health and environmental factors produced a list between the extremes of minimal requirements to comply with regulations and a comprehensive list that could be achieved with an unlimited budget (Figure 2).

Emissions considerations must incorporate civilian regulations established by the EPA, such as the National Ambient Air Quality Standards (https://www.epa.gov/criteria-air-pollutants/naaqs-table) and the Clean Air Act (42 USC §7401 et seq (1970)), for the system to be permitted for use in the guidelines established as Military Exposure Guidelines.[27] Additionally, the Overseas Environmental Baseline Guidance Document[28] is applicable for planning WTE use in a deployed contingency environment. The body of knowledge for emissions is well-researched, and specific studies for health and environmental concerns for individual and varied emissions classes are available.

Emissions analysis during WTE technology development and assessment will generally be restricted due to limited money and/or time. Testing comprehensive lists of emissions requires significant resources, involving a multitude of sampling trains, elaborate equipment sets, highly-specialized personnel, and considerable amounts of time. The extensive resources for sampling are required because there are no test methods, continuous emissions monitoring equipment, or direct reading instruments that can analyze all emissions concurrently. While some emissions such as $CO_2$ can be quantified at low costs with easily procured instruments, the vast majority of analytes of interest require ample time and money. Previous research has studied the feasibility of using emissions such as $CO_2$ as surrogates to estimate other emissions constituents. However, surrogate testing may be only informative for exposure assessments in austere conditions and does not replace the need for a full suite of testing.[29] It is important to note here that detailed emissions analysis is necessary for the DoD to definitively understand emissions from potential WTE systems before they are developed and fielded. Therefore, a prioritized list of emissions and standardized testing methodology must be established to maximize efficiency and minimize testing costs.

## DoD Energy Initiatives

At the time of this writing, the DoD approaches the concepts of operational energy very differently than it has in the past. This shift is in part a result of current budgetary environments, but also the acknowledgement of senior leadership that energy efficiency can be a force multiplier if applied correctly. Lessons learned from OIF/OEF highlight that capabilities which reduce energy consumption, simplify logistics, and impart greater combative stamina to the Warfighter are of unquestionable value. To that end, there are several efforts within the DoD focused on aligning US military forces with future strategic goals, such as reductions in energy dependence and increased energy efficiency, without hampering the ability of the Warfighter. As a specific example, the Marine Corps Expeditionary Energy Office was established on October 1, 2009, charged with the mission to "analyze, develop, and direct the Marine Corps' energy strategy in order to optimize expeditionary capabilities across all warfighting functions."[30]

The Marine Corps *Initial Capabilities Document* for *Expeditionary Energy, Water and Waste*[31] (ICD) outlines 3 primary objectives: (1) Achieve resource self-sufficiency on the battlefield, (2) reduce energy demand in platforms and systems, and (3) reduce the overall footprint in current and future expeditionary operations. The ICD formalized the need for analyzing waste as a step forward to achieve energy efficiency, curtail dependency, and reduce resource requirements to handle waste. Moreover, the ICD confirmed that waste management is inextricably tied to energy efficiency and consumption. In the most illustrative example, waste disposal in austere environments using burn pits can require in excess of a pound of fuel for disposal of 2 pounds of nonhazardous solid waste. This new focus on waste, coupled with waste management as an integral part of environmental considerations in base planning, has opened the possibilities for technology that can fill the dual role of waste disposal and energy production through WTE technologies.

Waste-to-energy technology is not an entirely novel concept; commercial industry has honed the technology

to marketable viability both domestically and internationally. In the private sector, the use of WTE technology has been gaining momentum as a potential tool to transform solid waste into usable energy which supports efforts to manage waste in a closed loop fashion.[32] However, DoD's requirements to deploy equipment dictates the miniaturization, containerization, and application of these systems into harsh austere environments that are new design challenges for the technology. Currently, waste handling in deployed environments can be accomplished several different ways; US forces managing disposal, contractor disposal, burying, contracting to third country nationals, incineration, burn pits, and burying, to name a few. However, in 2011, in response to concerns of exposure from burn pit emissions, *DoD Instruction 5715.19*[33] established as policy:

> …the prohibition of the disposal of covered waste in open-air burn pits during contingency operations, except in circumstances in which no alternative disposal method is feasible.[33(p1)]

## Framing the Problem for DoD-Specific Waste-to-Energy Systems

To effectively fill the gap created by the avoidance of burn pit use in deployed waste management plans, it is important to first understand the operating environment and nature of DoD's problem.[34,35] Compared to planning for US operations, or deployment into austere but permissive situations, deployed waste management at the far forward tactical edge faces challenges which are unique to these potentially hostile and expeditionary settings. Common operational environment considerations include items such as geography, local economy, climate, and time. However, the threat of enemy hostilities, which are continually adapting to exploit perceived weaknesses, are the defining characteristic that differentiates DoD applications from other austere WTE solutions such as island nations, remote rural communities, etc. In past operations, open-air burning of solid waste allowed deployed personnel to maintain focus on essential tactical tasks in the face of enemy threat. However, technological advancements have rendered rudimentary burning and similar methods far less advantageous. It is now necessary to choose a suitable alternative to burn pits that provides the same simplicity, convenience, and reliability without exposing service members to hazardous air emissions.

Guided by efforts to promote health and sustainability, the "objective of waste management is to minimize the potential harm and cost" of waste, which may be accomplished by "developing options that are feasible, suitable, and sustainable."[36(p1-2)] To better understand the nature of the problem and how to develop alternative disposal options, limitations should also be considered.[34] Waste disposal operations are strictly regulated by federal law in the United States for garrison and training. However, waste disposal policies mandated in the United States do not always extend into deployed environments due to constrained resources and shifted priorities—force protection often supersedes environmental protection in hostile environments. Expeditionary manpower, time, and resource limitations demand careful consideration. Expeditionary forces must conduct combat operations, in addition to day-to-day waste management, with only the manpower and resources organic to their unit. This fact will influence the development of disposal options and the respective attribute trade-offs. For example, contracting local nationals to conduct waste disposal is cost efficient, benefits the local economy, and frees military personnel to focus on tactical tasks, but it also exposes personnel to the possibility of attack from within their contingency base. Similarly, although WTE systems have the potential to reduce energy consumption and volume of waste, they cannot do so at the cost of continual manning, excessive segregation/pretreatment of input waste, or extensive maintenance.

Austere contingency base camps continually face enemy threats and pose particular challenges that presuppose the "one-size-fits-all" WTE solution that city-sized US installations often enjoy (eg, large waste feedstock supply and ample non-Warfighter contractor support). In addition, mere interservice differences in concepts of operations, tables of organization, tables of equipment, and budgets also impose limitations on joint courses of action. For example, naval shipping, where space is already limited, must conform to specific container dimensions and weights. Air Force lift capabilities face another strict set of shipping requirements related to container volume and weight. Army and Marine Corps units have different organic heavy equipment capabilities, which also affect the physical design and transportability of a candidate WTE system. Not surprisingly, these differences, among others, have driven the development of widely varying WTE systems that military decision-makers may consider in disposal planning.

Nonetheless, voids still exist in information relating to the deployed waste stream and WTE systems. Due to natural variability, there is still much uncertainty about deployed life-cycle disposal costs, waste composition, generation rates, and the available latent energy, despite the development of a standard deployed "waste recipe." This uncertainty will be a source of risk in both acquisition and planning. Based on a typical military waste stream feedstock, data should also be collected on net energy conversion efficiency, combustion efficiency,

and air emissions. Therefore, standardized WTE test procedures and analysis reflecting the unique deployment environment should be implemented to improve the deployability and effect on force protection of expeditionary waste management.

## Deployed Waste Management Practices

Waste management requires attention and resource dedication across the spectrum of military operations as a function of environmental considerations. Waste management must be deliberate whether the conditions are garrison and training activities, initial and mature combat operations, or peacetime operations such as foreign humanitarian aid or humanitarian assistance/disaster relief scenarios. The joint Army/Marine Corps publication *Environmental Considerations*[1] comprehensively outlines the commander's responsibility to ensure adherence to such considerations. Improper waste management has the potential to adversely affect force health protection through uncontrolled spreading of disease (disease vectors), exposure to hazardous materials, and exposure to hazardous waste. Understandably, doctrine guides commanders to place a lower priority on environmental considerations as necessitated by a threat analysis. However, if feasible, effective waste management can reduce logistical burden, promote host-nation good will, and enhance postconflict stability.[36]

As discussed earlier, similar to the wide-ranging scope of environmental considerations, military base sizes and planning factors have an extensive range as well. The joint Army/Marine Corps publication *Base Camp*[2] details the factors that influence establishing and maintaining military base camps. Base camps are classified into 4 sizes by population as shown in Table 1.

Table 1. Base Camp Classification by Population.[2]

| Base Camp Classification | Population |
|---|---|
| Extra Small | 50-299 |
| Small | 300-1,999 |
| Medium | 2,000-5,999 |
| Large | ≥6,000 |

Smaller base camps tend to be more unique and military-specific with focused combat functions. Larger camps tend to function in a manner similar to small cities, as they are hubs for personnel and logistics to sustain forward extended forces.

## Military Specific Waste Characterization

A full understanding of base camp waste streams (composition and characteristics) is important to inform the research and development of WTE systems. Aside from percentage composition of various waste categories, the actual physical and chemical characteristics help determine WTE technology suitability and its effective design. Characteristics of specific weight (or bulk density), moisture content, chemical composition through an "ultimate analysis," and energy content determination will encourage the best WTE system design. Each characteristic affects how the WTE system will perform with the waste stream that it thermochemically treats (ie, combustion). Moreover, waste streams also vary according to base camp size and mission set.*

Through the Joint Deployable Waste to Energy (JDW2E) working group, DoD is considering WTE as a possible solution to its waste management problems. Most historical waste stream characterizations have been performed on medium and large (Table 1) base camp sizes. However, JDW2E has determined that deployable containerized WTE implementation within the DoD will be at the extra small and small (Table 1) base camp sizes. Other than the waste analysis performed in the Philippines in conjunction with the bilateral 2015 Amphibious Landing Exercise-Philippines (PHIBLEX), only one other US military waste stream characterization has been performed at smaller base camp sizes with the same methodology (Fort Hunter Liggett (FHL), California). The FHL study was performed on the 4th Naval Construction Battalion (N≈500) during their field exercise.[37]

The FHL and the PHIBLEX studies used the American Society of Testing and Materials (ASTM) D5231-92(2008)[38] as the framework for their waste composition methodology. This is also a common standard used for other waste composition studies.[39-42] Waste stream analysis has been affected by the characterization methodology used.[43,44] Therefore, JDW2E has narrowed its focus on waste characterizations that adhere with this common methodology to aid in comparison studies.

The JDW2E community is focused on contingency base camps for use of deployable WTE systems because contingency base camps have historically used open-air burn pits as a primary waste disposal option. Although the PHIBLEX 2015 study was performed during an exercise, the waste stream closely resembled the contingency base camp environment due to the types of simulated combat operations (eg, live-fire ranges, close-air support integration, logistics convoys) and the activities performed within the camp (eg, maintenance on vehicles, medical tents, billeting, mess tents serving field rations, etc). The PHIBLEX 2015 study was the only military waste stream study that has met all 3 requirements of a smaller base camp size, ASTM standard methodology, and contingency base camp focus. Additionally, to date it is the only military waste

*Internal, restricted access military document not accessible by the general public.

study that was performed in the Pacific theater, an area to which the United States has increased its focus of effort.[45-47]

The waste composition study was conducted on the waste stream produced by US Marines at the Crow Valley base camp.* The population at Crow Valley was 800-1,300, so the camp was classified as small.[2] The waste was predominantly composed of food (28.2%), cardboard (19.7%), and total plastics (15.3%). The waste stream revealed military and contingency-types of waste due to the highly combat-simulated base camp environment and activity. Ammunition (5.56x45mm NATO), medical waste (used intravenous kit with needles), and hazardous waste (rags soaked with petroleum, oils, and lubricants) were found in the waste stream, despite prohibitions against such disposal. Figure 3 shows the composition of the PHIBLEX waste stream. Table 2 presents the 21 different waste categories that were assigned during the PHIBLEX study.

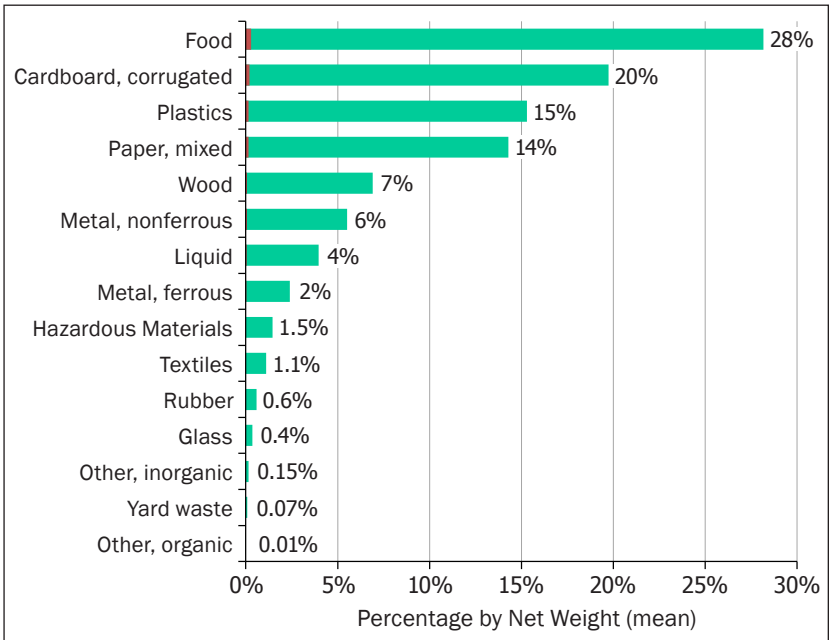


Figure 3. Composition of waste stream for the Crow Valley base camp in the Philippines during PHIBLEX 2015. Note: all 7 plastics categories were consolidated into one data component for this chart.

## Waste Groupings and Comparison

In an attempt to distill the salient points of the various waste categories into an analysis with more utility geared for WTE technology, 4 "waste groupings" were created to standardize the waste compositions for objective comparison: total plastics, moisture, combustibles, and metals/inorganics/other. Statistical comparisons were made after combining the waste categories into these 4 groupings.* In a government report,[26] the Army Research Laboratory (ARL) redefined the original 4 waste categories into 10 waste categories as the ASTM standard recommended.[38] Their analysis compared various military waste compositions and created a standard waste recipe presented in Table 3. When these 10 categories are grouped again into the 4 waste groupings, superficial percentage comparison suggests that the PHIBLEX 2015 waste is similar to the proposed standard waste recipe as shown in Table 4. However, detailed statistical analysis revealed that percentage composition did not suggest waste stream equivalency.* This was verified by using the nonparametric Wilcoxon/Kruskal-Wallis Rank Sums Test and the Dwass, Steel, Critchlow-Fligner Multiple Comparisons Test where *P* values were compared against $\alpha=0.1$.

Table 3. Army Research Laboratory Proposed Waste Standard Recipe.[26]

| | Categories | Composition |
|---|---|---|
| 1 | Cardboard | 15% |
| 2 | Mixed paper | 10% |
| 3 | Food Waste | 32% |
| 4 | Total Plastics | 15% |
| 5 | Wood | 14% |
| 6 | Metals | 6% |
| 7 | Glass | 1% |
| 8 | Rubber & Neoprene | 1% |
| 9 | Textiles | 3% |
| 10 | Misc/Other | 3% |

*Internal, restricted access military document not accessible by the general public.

In-depth statistical comparison may suggest that there is a difference. Inherent food waste difference is acknowledged between the 2 waste streams (actual vs representative); for example, the Army Research Laboratory report[26] used dog food as an easily obtainable, shelf-stable surrogate to simulate the food waste observed in an actual base camp. Additionally, clean and new (virgin) plastics were used instead of moisture-laden, soiled plastics that are typically found in the field.

## Energy From Waste: A Possible Solution

Waste characterization studies are the backbone of understanding military waste and the data collected is essential for WTE technology development. The studies form the basis of what materials and waste mixtures are used in simulated predetermined waste recipes, the starting point to test systems for DoD application, energy recovery potential, volume reduction, and health and environmental impact. As discussed earlier, emissions can be significantly lowered by burning waste in a controlled environment, where high temperatures can be maintained and smoldering conditions (which produce higher emissions) can

Table 2. Waste Categories and Generation.

| | Categories | Description | Content Example | Mean Composition [%] | Average Daily Generation [lbs] |
|---|---|---|---|---|---|
| 1 | Polyethylene Terephthalate (PET) | Resin Code #1: Most common thermoplastic polymer resin consists of polymerized units of the monomer ethylene terephthalate, with chemical formula $(C_{10}H_8O_4)_n$ | Water bottles; beverage/food/ cleaner bottles | 2.5% | 97.4 |
| 2 | High-Density Polyethylene (HDPE) | Plastic Resin Code #2: A polyethylene thermoplastic made from petroleum | Bottles, trash/cereal bags, sauce packets | 0.5% | 20.3 |
| 3 | Polyvinyl Chloride (PVC) | Plastic Resin Code #3:Third-most widely produced plastic, chemical formula $(C_2H_3Cl)_n$ | Film (cling wrap), construction materials | 0.4% | 5.0 |
| 4 | Low-Density Polyethylene (LDPE) | Plastic Resin Code #4:A thermoplastic made from the monomer ethylene | MREs food bags/wrappings | 6.8% | 321.2 |
| 5 | Polypropylene (PP) | Plastic Resin Code #5: A thermoplastic polymer with chemical formula $(C_3H_6)_n$ | Cereal containers, medicine bottles, straws | 1.1% | 67.2 |
| 6 | Polystyrene (PS) | Plastic Resin Code #6: Synthetic aromatic polymer, chemical formula $(C_8H_8)_n$ | Styrofoam, utensils, disposable food containers, MRE packaging | 2.0% | 98.9 |
| 7 | Other Plastics | Plastic Resin Code #7: Other Plastics not categorized/labeled with Code #1-6 | Reusable water bottles, UGR food trays | 2.0% | 82.6 |
| 8 | Food Waste | Discarded solid food leftovers/scraps originally intended for human consumption | Field chow hall, UGRs, or MREs | 28.2% | 1510.7 |
| 9 | Mixed paper | Recyclable paper | High-grade paper: office paper; paper trays | 14.3% | 498.3 |
| 10 | Corrugated Cardboard | Corrugated heavy-duty paper or paper-based fiberboard consisting of a fluted corrugated sheet and one or two flat linerboards. | Boxes | 19.7% | 1131.3 |
| 11 | Metals, Ferrous | Alloys that contains a significant amount of iron. Ability to magnetize. | Food-grade cans from UGRs; banding Wire | 2.4% | 98.9 |
| 12 | Metals, Nonferrous | Alloys that do not contain a significant amount of iron. Does not magnetize. | Aluminum cans, individual MRE packages | 5.5% | 194.4 |
| 13 | Other Organics | Combustible waste that does not fit in other waste categories | Insects | 0.0% | 0.1 |
| 14 | Other Inorganics | Noncombustible waste that does not fit in other waste categories | Concrete, asphalt, soil, stone, cigarette ash | 0.2% | 6.0 |
| 15 | Wood | All wood types from trees or woody plants | Bamboo, construction wood (lumber), pallets | 6.9% | 370.1 |
| 16 | Yard Waste | Biodegradable waste which was once a plant (garden waste) | Leaves, parts of bushes/vegetation | 0.1% | 0.0 |
| 17 | Liquids | Any fluid | Liquids remaining in bottles | 4.0% | 176.3 |
| 18 | Glass | Transparent solid composed of $SiO_2$ | Vehicle windshields, glass bottles | 0.4% | 12.8 |
| 19 | Hazardous Waste | Substance that poses a threat to human or environmental health | Needles, medical waste with blood, MRE heater | 1.5% | 59.3 |
| 20 | Textiles | Cloth that was woven with fibers like thread or yarn | Socks, uniforms, parachute cord, t-shirts | 1.1% | 44.2 |
| 21 | Rubber | Highly elastic solid substance (synthetic or natural) | Tires, seals from ordnance packaging | 0.6% | 26.0 |
| | | | | 100.0% | 4820.7 |

be eliminated.[24] Consequently, destruction of waste in a controlled and contained manner increases the possibility of harnessing usable energy from waste. There have been several technologies developed to handle municipal solid waste (MSW) in WTE systems, each with specific design characteristics such as throughput, preprocessing, power output, etc. Figure 4 outlines currently available processes to transform waste into thermal energy and depicts the major steps involved for each

Table 4. Comparison of Waste Groupings.

| 4 Waste Groupings | PHIBLEX 2015 | ARL Standard Waste Recipe[26] |
|---|---|---|
| Total Plastics | 15.3% | 15% |
| Moisture | 32.1% | 32% |
| Combustibles | 42.7% | 43% |
| Metals/Inorganics/Other | 9.9% | 10% |
| Total | 100% | 100% |

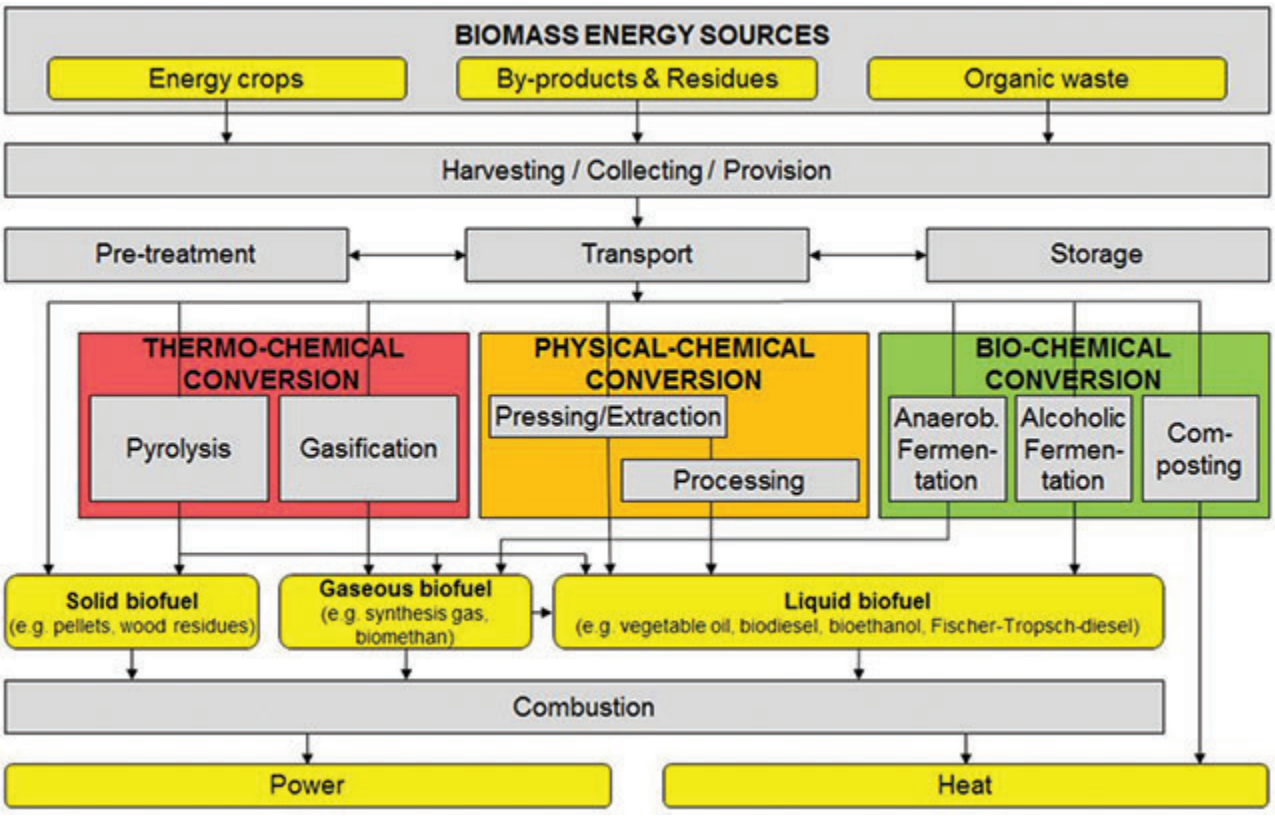


Figure 4. Biomass energy sources. Adapted from *Energie Aus Biomass*[49] with permission of its authors.

method. Not unexpectedly, there are physical and thermochemical limits to the current technology that rely on waste stream input volume and footprint requirement. With that in mind, there are only 4 physical processes that are practical to support processing of military-specific waste at extra-small and small base camps: direct combustion, combustion, pyrolysis, and gasification.[49]

Direct combustion is a relatively simple process, as it requires minimal preprocessing of the waste feedstock. Drawbacks to direct combustion are the creation of fly ash, absence of scrubbing systems to remove toxins from air emissions, and, qualitatively, negative public perception.[49] Nonetheless, despite the lack of dedicated air emission handling systems, direct combustion systems usually provide better burn conditions, increased combustion efficiency, higher temperatures, reduced smoldering conditions, and cleaner emissions over conventional burn pits. Direct combustion systems provide a technologically simple method for waste disposal by achieving volume reduction and relatively cleaner emissions.

Another option is thermochemical processes that convert waste into a secondary energy (liquid fuel) which "allows for a cleaner and more efficient process…smaller flue gas volumes allow reduced gas cleaning equipment sizes" and "are compatible with gas turbines and gas motors, characterized by a high electrical efficiency."[50] As WTE systems aim for maximum efficiency and energy recovery, their designs become exceedingly complex (such is the case in gasification and pyrolysis-based systems), the physical characteristics and "quality" of the fuel source become increasingly important. Municipal solid waste is a heterogeneous fuel source. It varies widely in moisture content, material size, and the composition is generally at the mercy of the supported community. Processes to transform waste to a more homogenous refuse derived fuel are available and have been investigated. Refuse derived fuel (RDF) can be generated from MSW by "shredding, screening, sorting, drying and/or pelletization in order to improve the handling characteristics and homogeneity" of MSW.[50] The Bosmans and Helsen[50] review of WTE technologies focuses on RDF, due to the fact that systems such as pyrolysis and gasification require homogenous waste streams to achieve maximum efficiency. Transforming and processing waste is an additional design consideration that adds complication to the waste disposal process and must be carefully considered while designing a mobile and dependable solution for deployed forces in austere environments.

System complexity is an extremely important consideration. Generally, air emissions decrease as system complexity increases (ie, burn pits to gasification/pyrolysis). The tradeoff for better emissions is increased system intricacy and overall weight. Figure 5 illustrates the progression and tradeoff expectations for transitioning from burn pits to various WTE systems.

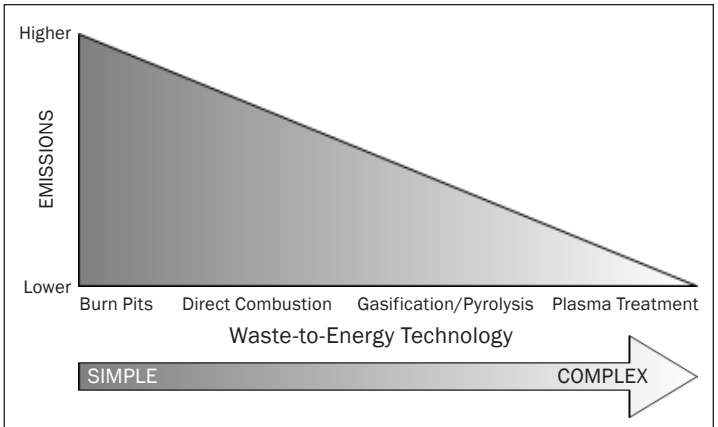

Figure 5. Waste management system complexity vs emissions.

Removing toxins from emissions is an important consideration for WTE systems and can be achieved by adding various cleanup technologies (known collectively as air pollution control devices) to exhaust systems. Adding scrubbing systems to any WTE technology raises the complexity of a system and must be carefully considered for use in contingency environments where skilled maintenance support will be limited. Irrespective of specific technology approach, WTE broadly promises volume reduction of waste in excess of 95% of original dimensions and reduced emissions as compared to open burn pits. Waste volume reduction is directly aligned with the strategy established by the DoD as outlined in the *Strategic Sustainability Performance Plan*.[51]

The goal is for the DoD to provide a safer alternative than burn pits to service members deployed in an austere environment and not hinder or unnecessarily burden their mission, potentially turning what is currently a logistical burden into a potential energy resource. If a WTE system is developed for this purpose, testing and development protocols must align to simultaneously address the health risk concerns, waste processing requirements, and DoD specific deployment considerations (maintenance, durability in shipping, ability to operate in diverse environments, mobility, etc). The only way to accomplish this goal is accurate problem definition and conscientious service member input during all stages of system development.

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US Marines observing smoke plumes from an open air burn pit in Afghanistan, September 2008 (DoD image).

# Animal-Assisted Health and the Performance Triad

MAJ M. Todd French, VC, USA

## The Performance Triad and the Military Family

In 2013, the Army Surgeon General's office unveiled an innovative health promotion and fitness plan known as the Performance Triad (often simply referred to as "the Triad").[1] The Triad is the first initiative of the larger "System for Health" concept. The mission of a System for Health is to involve all aspects of the military community in the goal of promoting health and wellness, preventing illness and injury, providing high quality care, and positively influencing behavior and environments where beneficiaries live, work, and play.[2] The Army Medicine website describes the Performance Triad and its place within the System as:

> A comprehensive plan to improve readiness and increase resilience through public health initiatives and leadership engagement. The Triad is the foundation for Army Medicine's transformation to a System for Health, a partnership among Soldiers, Families, Leaders, Health Teams and Communities to promote Readiness, Resilience and Responsibility. The System For Health: MAINTAINS health through fitness and illness/injury prevention, RESTORES health through patient-centered care, and IMPROVES health through informed choices in the life space.[2]

COL Deydre Teyhen, current director of the Army Surgeon General's System for Health, described the program to the *Army Times* as a tool to help Soldiers understand the effect of altering unhealthy habits and achieving better fitness through "the small, simple changes they can make."[1] The goal is to enhance overall fitness through development of an individual plan that helps Soldiers realize the positive health outcomes that accompany healthy choices. These ideas are reflected in the program's basic message: engage in activity, improve nutrition, and get quality sleep. Though the Triad premise is simple, the overall concept represents a unique shift away from compartmentalized fitness and towards holistic prevention and proactivity practices.[3]

The Triad also widens the lens to recognize the positive effect that a Soldier's family can have on the Soldier's overall health. A recent demographics profile found 55.3% of the active duty military community is married, 42.2% have children, and family members outnumber active duty service members by more than 450,000.[4] These statistics indicate a potentially robust role for family integration into the Triad. Military families excel as members of an active community. One study showed that military spouses exercise substantially more than comparable civilian groups, and military children tend to participate in physical activity more than other children their age.[5] Military families have also been shown to provide a strong foundation for mental well-being, social support, and resilience in the face of the uncertainty characteristic to military service.[6,7] Overall, a Soldier's family likely plays a key role in implementing lifestyle changes related to improving activity, nutrition, and sleep.

## Military Pets: Four-Legged Family

Companion animal ownership is com mon within military families. A recent report from the US Army Public Health Center (not publicly accessible)[8] enumerating patient records from all veterinary facilities located on Department of Defense installations worldwide shows that there are currently over 360,000 pets registered at military facilities in the contiguous 48 United States, and over 86,000 registered at facilities outside of those states (mainly Europe and Asia). Not only does the military community have an abundance of pets, most consider pets to be a part of the family. A survey of 896 military families with pets showed that 98% considered their pet a family member or close friend, 75% said that their pet was of great importance to the family at all times, and 72% indicated that their pet had "people status" within the family.[9] Another survey examining military families with pets transferring from Hawaii found that 99% considered their pets as family members, and 96% had at least one family member experience temporary or chronic sadness if the pet had to be left behind.[10] Despite the difficulties, military families form strong attachments to their pets and have been shown to be more willing to accept the additional responsibilities associated with ensuring their pet is a part of the frequent relocations inherent to service.[11] In short, military pet owners clearly appreciate their 4-legged family members, but many may not realize that the relationship has the potential to boost their health.

## Health Benefits and the Human Animal Bond: A Review

Researchers have investigated the human-animal bond and its effect on overall well-being for years. In addition

to the abundance of anecdotal evidence that animals "just make us happy," there are evidence-based data that support the positive association between animal ownership and long-term health. The evidence supporting companion animals and cardiovascular health is particularly persuasive.

In a landmark study examining one year survival time in heart attack victims after discharge from a coronary care unit, Friedmann et al found that pet owners survived at a rate over 4 times greater (28%) than non-pet owners (6%).[12] Allen et al discovered that high blood pressure and heart rate could be significantly reduced by way of pet ownership, even in a population at risk for cardiovascular disease (preexisting hypertension) engaged in a high stress career (stockbrokers).[13] Anderson et al, in a study of 5,700 (784 pet owners), also found that sharing a house with a companion animal was not only associated with lower systolic blood pressure and heart rate, but significantly lower blood cholesterol and triglyceride levels.[14] Several other studies have also connected pets in the household to heart health.[15-17] In fact, the data linking the two is so convincing that the American Heart Association released a policy statement indicating that pet (particularly dog) ownership is probably associated with decreased cardiovascular disease risk, and may play a causal role in disease prevention.[18]

Cardiovascular health is not the only health benefit derived from pet ownership. Pets have also been shown to positively influence total health and well-being. For instance, a 10-month study on adults adopting animals from an animal shelter found a significant reduction in participants' minor health problems for the entire 10 months following adoption.[19] Other studies have provided compelling evidence that owning cats and dogs as a child can actually decrease the likelihood of acquiring asthma or allergies.[20-22] Researchers have also provided empirical data to strengthen anecdotal claims that pets "just make us happy." Odendaal discovered that hormone levels of dopamine and endorphins associated with happiness and well-being increase following only 30 minutes of dog interaction—and the same increases were observed in the dogs.[23] Lastly, dog walking and interaction has become a recommended method to prevent chronic disease.[24]

Pets not only help prevent chronic disease, they promote health through a variety of avenues. The consensus in the scientific community is that pets do a remarkable job of increasing physical activity, improving our mood and emotional state, decreasing mental stress, and providing companionship.[25] In addition to the obvious health benefits of increased physical activity, decreasing stress and providing social support through companionship may be the most significant role that pets play in human health.

Stress management likely represents an essential gateway to health for service members. A recent index of job stress scores puts military service behind only firefighting as the most stressful job in the United States.[26] While a certain amount of intermittent stress can benefit the brain and body, a high degree of stress can be harmful.[27] Stress overload can eventually exhaust the ability to adapt and lead to deleterious and chronic health changes.[28]

Due to its ease of collection, stress researchers typically correlate reductions in stress to reduction in the stress hormone, cortisol, in saliva.[29] This method translates well to human-animal bond research as it is quick to measure stress response even during brief interactions. For example, Odendaal showed that cortisol reduction was significant in just a 30-minute session with a dog.[23] Barker et al mirrored those results revealing that cortisol levels in healthcare professionals, another high stress career, could be reduced after as little as 5 minutes of interacting with a hospital visitation dog.[30] Cortisol reduction is also used as a marker to determine the success of using service dog training programs to treat service members suffering from posttraumatic stress disorder.[31] Fortunately, similar research reveals that dogs (even those enlisted in visitation programs) have reductions in cortisol as well when interacting with humans.[23,32,33] Beyond this experimental evidence on stress reduction, pet owners consistently indicate that they just "feel" that pets reduce their stress levels.[34,35]

Social support is an integral, though difficult to measure, path through the gateway to better health. The evidence linking social support to overall well-being and host resistance to disease is strong.[36-38] Thankfully for pet owners, animals play a useful part in the family social support network. Not only do pets offer direct support through the close owner relationship, they support indirectly by acting as a "social ice breaker."[35] In a 2-tiered study examining dogs as social catalysts, McNicholas et al discovered that an individual performing normal daily activities with a dog had an increased frequency of social interactions, especially with strangers, when the dog was present irrespective of the way the individual was dressed.[39] Another study investigating the behavior of 1,800 pedestrians passing an adult participant with a dog, a teddy bear, or a plant found that dogs facilitated the most reliable social interactions.[40] Naturally, pets have been shown to also promote pro-social and learning behaviors in children.[41]

## Animal-Assisted Health and the Triad: Forming Actionable Goals

The scientific literature certainly fortifies the family pet's role in supporting long term health, stress reduction, and the family social network. The question becomes, "how does this support help military families make Triad goals actionable?" In outlining the Performance Triad, Army Medicine mentions that a key component to goal setting is to focus on improving health within the life space. The life space refers to the approximately 525,000 minutes in a Soldier's year that they are not with a healthcare provider (≈100 minutes).[42] Obviously, time in the life space predominates. Those that adhere to the tenets of the Triad are urged to use this time to make "small, simple" lifestyle changes that will become their roadmap to better health and fitness. This is also the time that family pets can be most influential to improvements in activity, nutrition, and sleep. The author believes that this integration of pets into a cooperative health and fitness plan can best be described as "animal-assisted health."

### Engage in Activity: Animal-Assisted Health

The military culture, by its nature, supports an active population. Those who serve are reminded of this in everything from the rigors of basic training to the command designated time for physical fitness. Even the official songs of the 3 main military services allude to activity through verses inspiring their charges to, "march along," "climb high," and go "full speed ahead." Service members are required to maintain a high level of physical fitness and are assessed on it frequently. The mere expectation of physical fitness, however, is not always enough to motivate obedience to activity. Predictably, attitude matters when it comes to adherence to an exercise program.[43]

Lack of motivation to perform scheduled physical training may be of particular concern in the military. Military members are normally expected to participate in a physical training program with their unit regardless of desire to attend. Lack of desire can lead to lack of focus during the program which may ultimately result in a lower level of fitness. The unfortunate consequence of a low fitness level is that it has been shown to be a predictor of musculoskeletal injury proneness in the military.[44] Noted sports psychologist, Dr Bill Morgan, suggests that a paradigm shift in approach to exercise might increase loyalty to physical activity. His suggestion is to supplement nonpurposeful with purposeful exercise.[45] The idea is that individuals will be more apt to adhere to exercise if it serves a purpose. Morgan also suggests that one of the most common purposeful activities is walking, or running, the family dog.

It is a given that dogs need to go outside several times a day to fulfill biological needs. One of those biological needs, of course, is the need to exercise. In his article, Morgan describes a presentation at the American College of Sports Medicine which points out how that can also be beneficial to the human need for exercise:

> The famous Norwegian Psychiatrist, Dr Egil Martinsen, suggested in a colloquium he presented at the American College of Sports Medicine several year ago, that if a patient is considering an exercise machine, a dog would make for a good selection! Consider the situation where one awakens to discover that it is raining, snowing, or perhaps he or she just does not feel so well. It is very easy to put off a daily run or walk under these circumstances, but if the individual has a date (pact) with his or her dog, skipping the daily exercise is simply out of the question.[45(p369)]

Dog owners may make this "pact" without realizing just how mutually beneficial it can be. Several national surveys already indicate that dog owners exercise more than non-pet owners.[14,46-48] This should, again, come as no surprise as walking a dog is a purposeful activity. It is theorized that dog walking may remove the barriers (ie, excuses) to participating in physical activity by using the social support channel created through the human-animal bond.[24,47] Essentially, this theory expresses the common view that it is often more enjoyable to work out with a buddy.


Figure 1. Army Medicine fully supports integrating family pets into the Triad. This poster depicts an owner engaged in purposeful activity with her dog Bella. Poster courtesy of the US Army Public Health Center.

The author believes that an increase in enjoyable exercise will accompany the realization that walking, or running, with the family pet is purposeful physical activity (Figure 1). Viewing the activity as a pact will likely hold the owner accountable and increase dedication to the act. An increase in dedication to physical activity might improve fitness levels and decrease the chance for musculoskeletal injuries during a military member's required unit physical training sessions That being said, small goals

should be set based on the size, stamina, and health of the dog and owner. For instance, a goal for those with small breed dogs may be to walk for a certain amount of time. A goal for larger, more athletic breed dogs may be to walk, or run, a certain distance. Time and distance should increase gradually based on the condition of both participants; a rigorous program should not be attempted for dogs or owners who are not properly conditioned. Obtaining the benefits of purposeful activity from a dog is also not limited to those that own dogs. Military members and their families have alternate opportunities available to them. In addition to simply "borrowing" a dog from a friend or family member, many animal shelters operated by local Humane Society chapters (www.humanesociety.org) have dog walking/running programs designed to socialize, condition, and increase the adoptability of shelter dogs.

### Improve Nutrition: Animal-Assisted Health

Physical activity and nutrition go hand in hand. Recommendations from the medical and public health community tend to focus on the combination of diet and exercise when addressing avenues to overall health. The reason for this focus has become increasingly evident in the past several decades as obesity rates have elevated to epidemic levels in the United States.[49] In fact, the issue has become of such concern that national health organizations, like Trust for America's Health, have sponsored on-line searchable databases that show the state by state effect of obesity (www.stateofobesity.org). Unsurprisingly, the Centers for Disease Control and Prevention recognizes the strong link between the components of obesity, unhealthy diet and physical inactivity, and chronic diseases like type 2 diabetes, hypertension, heart disease, stroke, and some cancers.[50]

It may seem counterintuitive in a physically demanding career, but military service members are not immune to the national overweight and obesity epidemic. A 2014 report revealed that obesity rates among active duty service members rose 61% between 2002 and 2011, and that 12% of the active duty force is currently obese.[51] The tendency towards excessive weight gain and obesity is also uncommonly high in military family members.[52] With physical activity and exercise reported to be higher in military families, as previously mentioned, poor nutrition, especially overeating, likely plays a much larger role in the epidemic.[53,54]

Unfortunately, pet obesity is likewise at epidemic levels in the United States. An annual survey on the issue recently indicated that almost 60% of the nation's 95.6 million cats and over 60% of the nation's 85.3 million dogs are overweight or obese.[55] The survey further points out that pets, like their owners, suffer from some of the same chronic diseases related to unhealthy weight gain. The issue of pet obesity is also big enough to warrant a website dedicated to obesity awareness and prevention, www.petobesityprevention.org. Research into the trend tends to emphasize the large role that poor nutrition plays in the problem. Most in the veterinary community believe that pets are also eating too much. A groundbreaking paired feeding study from the Purina Pet Care Center helped to solidify this concept in 2002.[56] The trial enlisted 48 Labrador retriever puppies from 7 litters. The puppies were paired within their litters according to gender and body weight; were randomly assigned to either a control group (fed ad libitum during daily feedings) or a lean fed group (fed 75% of the amount eaten by the littermates); and were weighed and had body condition assessed at consistent intervals. Incredibly, Kealy et al found that the overfed dog group not only died significantly sooner, 1.8 years, when compared to the lean group, they also required treatment for chronic conditions 2.1 years earlier than the lean fed group.

There appears to be some common ground to make mutually beneficial lifestyle changes given the connection between poor nutrition and human and pet weight gain. Improving nutrition does not require drastic changes. As the Triad guidance suggests, small changes can produce recognizable results. That being said, the most effective change may be for pet owners to follow the guidance that is given to their pets when an intervention for improved nutrition is prescribed by their veterinarian: choose high quality food, feed only to caloric needs, feed more than once a day, and decrease unhealthy snacking.

Successful dual nutrition plans have been explored through research. One such success was outlined in a program that paired 36 pairs of overweight or obese people with an obese pet to a control group (overweight or obese people with no pet).[57] Over the course of a year participants in the program received dietary, as well as physical activity, counseling and dogs were fed a calorie restricted diet. By study's end, owners with pets tended to stick with the program longer and had higher mean weight loss (5.2% compared to 4.7%, though this was not considered statistically significant). The dogs also greatly benefitted from engaging with their owners in the program as they had statistically significant weight loss and improvement in overall body condition.

Mutually beneficial nutrition improvement can be implemented within the family. The author believes that this can occur quite easily by following the guidance mentioned above. Choosing high quality food does not mean choosing the most expensive food; it means

checking labels to ensure that ingredients meet the suggested nutrient profile for the individual pet or owner. The US Food and Drug Administration requires that nutritional profiles be present on all packaged food, including pet food, and that ingredients be listed in descending amounts.[58] Feeding, or eating, only to individual caloric needs addresses the tendency to overfeed, or overeat. The American Animal Hospital Association also recommends that pet owners feed at least 2 meals a day as opposed to one large meal.[59] This matches recommendations published in the US Department of Health and Human Services *Dietary Guidelines for Americans 2015-2020* against eating large calorically dense meals.[60] These dietary guidelines urge replacing unhealthy snacks with healthier options as well. A particular parallel can be drawn between improving human and pet nutrition in regards to snacks. For instance, it is common practice for veterinarians to recommend that clients replace commercially produced animal treats with fresh or frozen vegetables to improve nutrition in overweight pets (Figure 2).[61] Therefore, having a bigger supply of vegetables in the house could actually help improve nutrition in the entire family.


Figure 2. Army Medicine fully supports integrating family pets into the Triad. This poster depicts an owner engaging in mutually beneficial nutrition practices with her dog Gracie. Poster courtesy of the US Army Public Health Center.

### Get Quality Sleep: Animal-Assisted Health

Of all the Triad goals, getting consistent, quality sleep is often the most difficult one to realize. Public health professionals agree as insufficient sleep is now considered a public health problem.[62] One national survey indicated that nearly 30% of adults averaged less than 6 hours of sleep a night.[63] Lack of sleep naturally disrupts the performance of both simple and complex tasks. As expected, those who do not get adequate sleep report that they have trouble concentrating on/remembering things, taking care of financial affairs, performing at work, and often nod off while driving.[62]

Military members are quite susceptible to sleep deprivation and its consequences. In fact, those who serve are at exceptional risk for poor quality sleep given the frequent high demands expected of the job. In their paper on lack of sleep as an emerging issue in the military, Brown et al[64] postulate that the problem represents a multifactorial relationship between personal health, habits, and lifestyle contrasting with the emotional and physical stress of the work. This is reflected in data from the large cohort of military members participating in the Millennium Cohort study* as poor sleep quality was significantly associated with lower rated self-health, more lost work days, and more healthcare utilization.[65] It is not just lack of sleep that is affecting military members either. The prevalence of those suffering from sleep disorders in the military is also on the rise.[66] It stands to reason that military family members also share this sleepless burden as they experience the unique stress of military life alongside the military member.

Companion animals, on the other hand, rarely have trouble sleeping. Dogs usually spend about 50% of their day sleeping and 30% lying around while awake.[67] Cats are even more prodigious sleepers as they are known to sleep as much as 15-20 hours a day.[68] Given this information, it is not hard to see why both animals are immortalized in idioms such as "let a sleeping dog lie" and "catnap." Nevertheless, anyone who has slept with a pet on their bed knows that there are difficulties inherent in the habit. Like humans, pets typically do not appreciate movement while sleeping and often reposition. This practice leads to sleep disturbances for all involved. Cats can be particularly poor bed mates due to their propensity for sleeping on top of their owners, and further complicate sleeping as crepuscular creatures (most active at dusk and dawn).[68]

Despite these potential sleep disturbing behaviors, a national survey reports that 45% of dogs and 62% of cats still share the pet owner's bed.[69] The common assumption is that co-sleeping with pets is ultimately a bad way to get quality sleep. There is research to support this statement; however, new research indicates that co-sleeping may actually be beneficial. Krahn et al[70] addressed the assumption in their 2015 report from the Center for Sleep Medicine in Arizona. A comprehensive sleep questionnaire, which probed into pets in the bedroom, was given to 150

*The Millennium Cohort Study is an ongoing longitudinal cohort study headquartered at the Naval Health Research Center in San Diego, California and designed to evaluate any long-term health effects of military service, including deployments. It is the largest population-based prospective health project in US military history, currently collecting data on over 200,000 enrolled participants. Information available at: http://millenniumcohort.org/.

consecutive patients. Of the 46 participants that co-slept with pets, only 20% described their sleep as disruptive whereas over 40% perceived the security, relaxation, and companionship provided by their pets to be an aid in achieving quality sleep.[70] Rose et al[71] also tout the benefits of co-sleeping, principally as a therapy for those prone to sleep disorders, in their 2015 *Sleep Review* article. They posit that the prescription of a co-sleeping pet or service animal may be a valuable, and underappreciated, accessory therapy for subpopulations, like veterans, who have difficulty obtaining quality sleep.


Figure 3. Army Medicine fully supports integrating family pets into the Triad. This poster features Darwin to explain the benefits of quality sleep. Poster courtesy of the US Army Public Health Center.

Medical professionals who work in the field of sleep science are beginning to understand that assumptions linking co-sleeping and sleep disturbance are not necessarily evidence-based.[71] Pets can actually be a very positive influence on military members and their families seeking to achieve the Triad goal of obtaining quality sleep (Figure 3). Another, more novel, area where they might be beneficial to pet owner's overall sleep is through napping. Dogs and cats both spend the majority of their daytime sleep in a light, nap-like, state.[67,68] This allows them to be roused easily and explains why they rarely miss a ringing doorbell or rustling treat bag when dozing. There is evidence that taking this cue to nap might be a good idea. Researchers have found that short naps (less than 30 minutes) can promote waking function after normal sleep and can even counteract decreased alertness and performance in the sleep deprived.[72] That being said, if co-sleeping helps some military families get a restful night's sleep, then "co-napping" might also prove valuable. This does not mean that pet owners should nap as often as their pets do because too much sleep can be just as harmful as too little.[73] It may mean, though, that pets play a part in a recharging 30 minute weekend nap on the couch. They may even help prevent oversleeping by acting as an adjunct alarm clock that springs to life at the opening of a refrigerator door.

## Conclusion

Companion animals are commonplace in military families. Most choose to share their home because of the companionship and perceived calming effect that pets provide through the human-animal bond.[74] Beck et al describe that this unique connection is the impetus for the quick transition from pet to family member:

> All indications are that companion animals play a role of a family member, often a member with the most desirable traits…For some, pets increase the opportunities to meet people, while for others pets permit them to be alone without being lonely.[75]

In addition to this role, pet owners consistently report that they believe that pets are good for the health of the family.[76] Those statements are backed by the scientific community. As referenced above, pets have been shown to provide well-being promoting social support and stress reduction, as well as tools to improve long term cardiovascular and immunological health.

Pets can also provide valuable animal-assisted health for those seeking to improve health and fitness through implementation of the Performance Triad. They can be a stimulus for their owners to perform purposeful physical activity which has been shown to help lowly motivated individuals stick to an exercise plan. Pet owners can team up with their pets and adopt mutually beneficial nutrition plans that can help both maintain a healthy weight. Finally, pet owners can explore the benefits of co-sleeping and co-napping with their pets which may be a useful aid to achieve better quality sleep. It should be noted that animal-assisted health may not be the best option for those who are indifferent to animals.[77,78] However, for those that value the human-animal bond, pets should be considered a potential asset on the path to better health.

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# Service Animals: A New Legal Dimension Within the US Military

Joseph B. Topinka, JD, MHA, MBA, LLM
Jack Nichols, JD
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Scenario 1:

An inpatient at a major military treatment facility (MTF) has a dog with him. No one on the ward wants to ask him whether the dog is a service animal. Instead, everyone on the ward takes turns walking the dog outside the facility until later in the day, when the charge nurse says enough. The nurse calls the command judge advocate of the medical center to confront the patient about his dog and where it will stay overnight. "This is a legal issue" states the charge nurse to the lawyer.

Scenario 2:

Months later, the same lawyer (Scenario 1 above) is having lunch in the MTF dining facility when he sees a group of people huddled together near one of the dining tables. He approaches the table, where he sees a family with a basket on the table that contains a little dog that everyone thinks is adorable. Another legal issue or a public health concern?

Scenario 3:

A Department of Defense dependent with a service dog arrives at her school located on a military installation. She is wheelchair bound, and the dog has been trained to assist her with many tasks, including pulling her chair and opening doors. She has an identification card showing that she and the dog have been certified as a service animal team, and it includes the applicable federal and state statutes. What does the principal do?

Real life scenarios? Yes. Two of the authors experienced these situations and, at the time, really did not have answers to the questions that were being asked: Was the inpatient's dog a service animal? Did the school have to accept the child's service animal in the classroom? If so, what were the patient's rights, and what were the facilities rights and duties under the law? Does the Americans with Disabilities Act (ADA) (42 USC chptr 126) control these scenarios, or can local policy supersede federal and state laws? Was the little dog in the basket a therapy or activity animal, or simply a companion, social animal, or a pet? Depending on its status, what legal restrictions or options were available to the administrative staff at these facilities? These questions are certainly not unique and, most likely, similar questions are asked every day at DoD facilities around the world as canine-assisted therapy in military medicine has become more prevalent over the years. In their 2012 article, Mills and Yeager[1] provided definitions of animals used in healthcare setting. This paper expands upon their article in light of recent DoD and Army policy on the issue of service dogs and the use of animals in the healthcare setting.

## Review of the Americans With Disabilities Act

The Mills and Yeager article focuses on definitions. Definitions are key when determining whether an animal fits within the protection of the ADA. Knowing definitions would have truly helped in the given scenarios, but, even with such definitions, the military has never been covered by the ADA in terms of service animals. Surprised? The requirements in Title II of the ADA were only applicable to "public entities," and federal government agencies such as the DoD and Department of Veterans Affairs (VA) were never included in the ADA definition of a public entity under 42 USC 12131(1).

A short overview of the structure of the ADA is necessary so that the reader can appreciate the difficulty, in general, involved in determining an animal's status as a service animal. First, the ADA is divided into 5 titles:

Title I addresses Employment and Equal Employment Opportunity for Individuals with Disabilities. Very often, managers see this part of the law in action during employment-related actions and enforcement through the US Equal Employment Opportunity Commission.

Title II deals with state and local government and affects nondiscrimination on the basis of disability in state and local government services. This title basically spells out how administrative processes are managed within state and local governments and their related organizations,

agencies, etc. It is regulated and enforced by the Department of Justice.

Title III deals with public accommodations and affects nondiscrimination on the basis of disability by public accommodations and in commercial facilities. This title does not deal with government entities at all, but it is also regulated and enforced by the Department of Justice.

Title IV addresses telecommunications and requires telephone and internet companies to provide individuals with hearing and speech disabilities with the ability to communicate through these media. It is regulated and enforced by the Federal Communications Commission.

Title V is a miscellaneous provisions section that contains a variety of provisions on the ADA as a whole, and it is more administrative in nature.

If the federal government were to fit under any title, the closest would likely be Title II, but its definitions only cover "any state or local government." To compound any misunderstanding, there is no definition of service animal within the ADA statute itself.

Definitions of service animals are found in the implementing regulations of the ADA in Title 28 in the Code of Federal Regulations (CFR) which are written by the Department of Justice. Title II is implemented through 28 CFR 35. Part 35, Section 104, which provides the following definition:

> Service animal means any dog that is individually trained to do work or perform tasks for the benefit of an individual with a disability, including a physical, sensory, psychiatric, intellectual, or other mental disability. Other species of animals, whether wild or domestic, trained or untrained, are not service animals for the purposes of this definition. The work or tasks performed by a service animal must be directly related to the individual's disability. Examples of work or tasks include, but are not limited to, assisting individuals who are blind or have low vision with navigation and other tasks, alerting individuals who are deaf or hard of hearing to the presence of people or sounds, providing nonviolent protection or rescue work, pulling a wheelchair, assisting an individual during a seizure, alerting individuals to the presence of allergens, retrieving items such as medicine or the telephone, providing physical support and assistance with balance and stability to individuals with mobility disabilities, and helping persons with psychiatric and neurological disabilities by preventing or interrupting impulsive or destructive behaviors. The crime deterrent effects of an animal's presence and the provision of emotional support, well-being, comfort, or companionship do not constitute work or tasks for the purposes of this definition.

Hero, a trained service dog, providing comfort and emotional support (in the role of animal-assisted activities) at the Occupational Therapy Clinic, Walter Reed Army Medical Center. Photo courtesy of Mills and Yeager.[1]

This definition is the same within Title III at Part 36, Section 104. In addition, both titles also address miniature horses in Sections 136 and 302 respectively:

> A public entity shall make reasonable modifications in policies, practices, or procedures to permit the use of a miniature horse by an individual with a disability if the miniature horse has been individually trained to do work or perform tasks for the benefit of the individual with a disability.

This last definition is the only exception to the standard rule that service animals are dogs.

## Reaction Within the Federal Government

Since the ADA does not apply to the federal government, and its definition of service animal is very limited, what have executive departments such as the VA and DoD done for Veterans and service members? How have they been able to get around their limitations but at the same time create policy that is within the spirit of the ADA in regard to service animals?

### Department of Veterans Affairs

The VA was able to take a more direct approach through its implementing regulations under Title 38 through the support of Congress in its amendment of 38 USC 1714 to authorize the VA to provide service dogs for Veterans with other disabilities. The statute was originally designed to provide dogs trained to aid the blind and

hearing impaired. The amendment "broadened and clarifie[d] current benefits to Veterans with guide dogs… and establish[ed] new benefits related to service dogs (77 *Federal Register* 172 (2012)). Critical to the VA's ability to adopt a regulation was the intent of Congress through the amendment. The VA did not implement a rule with a definition consistent with 28 CFR 36.104 because it was simply not the intent of Congress. The rule adopted (Title 38, Part 17, Section 148 (a)) was consistent with the administration of benefits to Veterans with service dogs:

> Service dogs are guide or service dogs prescribed for a disabled veteran under this section.

The VA's definition was simple yet broad, but also directly connected to the rest of Section 138 which goes into more detail about clinical requirements, service dog recognition, authorized benefits, and maintaining the ability to function as a service dog. One the one hand, the VA policy was in synch with the ADA in that it pertained directly to dogs. On the other hand, the policy had a specific veteran benefit focus and not Title II's focus on access to public facilities by individuals with disabilities.

### Department of Defense

The DoD approach was neither direct nor simple. In fact, the DoD's approach was a patchwork effort mostly led by the Army Medical Department (AMEDD). In 2012, Watkins[2] discussed policy initiatives for canines in Army medicine. Her article, along with that of Mills and Yeager,[1] provided a summary of what the AMEDD had done in terms of filling in the gap within the DoD pertaining to the use of canines and the use of animals in general within the healthcare setting. For example, Policy Memo 12-005[3] issued by the Army Medical Command (MEDCOM) in January 2012 was a comprehensive effort by the AMEDD to cover definitions and provide clear guidance to leaders in Army medicine concerning the use of animals. It relied on past policy, past practice, research, and adopting language of the ADA as stated in Policy Memo 12-005:

> …it is the [MEDCOM] commander's intent that MEDCOM facilities abide by these [ADA] provisions to as great a degree as is practicable and when such adherence does not hamper readiness.[3(p2)]

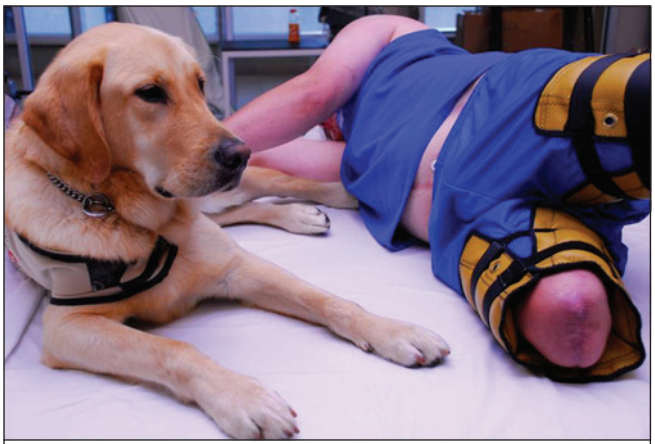
It was the type of guidance that would have been very useful for those of us who experienced the aforementioned scenarios (and other similar situations) at the time. There was simply no guidance within the military, and we had to piece together some advice based on a loose reading of the ADA along with simple common sense, which ultimately became the basis for the MEDCOM commander's policies. However, the MEDCOM guidance was not replicated within the other services, nor adopted by the entire US Army or DoD.

Two developments have occurred since the articles by Mills and Yeager[1] and Watkins[2] were published:

1. On January 28, 2013, Secretary of the Army John McHugh signed *Army Directive 2013-01*[4] which defined service dogs for the first time at the military secretarial level. The directive took some of the best aspects of the ADA and the OTSG/MEDCOM policy and made them official policy, Army-wide:

> a. Service Dogs. A service dog is a dog individually trained to do work or perform specific task for the benefit of an individual with a disability. Service dogs include guide dogs that assist individuals who are blind or have low vision with navigation and other tasks.[4(p1)]

2. On January 7, 2016, Acting Under Secretary of Defense for Personnel and Readiness Brad Carson, signed *Department of Defense Instruction 1300.27, Guidance on the Use of Service Dogs by Service Members.* This instruction's significance is the departmental level effort to standardize a definition of service dog and the use of service dogs across the entire organization, much as has been done by the VA. In addition, it refers to the definition of service dogs from both Title 28, Section 35.136, and Title 38, Section 17.148, in its overall purpose in establishing policy, assigning responsibility, and providing procedures department-wide. However, we believe that the definitions, including that of a service dog, fall short of providing the same measure of comprehensive guidance that OTSG/MEDCOM Policy Memo 12-005[3] provides in the medical setting. Its real focus is on the acquisition of service dogs for service members, particularly the standardization of that narrow issue. The



Raliegh, a facility animal, providing counterbalance during a physical therapy sesson (in the role of animal-assisted therapy) at the Military Advanced Training Center, Walter Reed Army Medical Center. Photo courtesy of Mills and Yeager.[1]

DoD instruction could have gone farther in providing meaningful standardization to all the services, both inside and outside of the medical setting. As written, it leaves a substantial amount of authority and discretion in developing and implementing policies regarding all animals, including service dogs, to the secretaries of the military departments. As a result, many gaps in the policy remain across DoD.

## Unfinished Business

We believe that more should be done in developing and implementing service policies pertaining to service animals. Title II and Title III of the ADA limit their definition of service animals to dogs and, in some instances, miniature horses. But what about all the other animals that are defined by Mills and Yeager[1] or in OTSG/MEDCOM Policy Memo 12-005?[3] If definitions are truly key when determining whether an animal fits within some type of protection, why have more policies not been published or developed, not only in the medical setting but at the installation level as well? Even if the services create individual policies to address their service, the implementation of the "joint-base" concept prevents one military service from implementing its specific policy on an installation controlled by another service. Should Congress be the ultimate deciding authority on this topic as it was for the VA? These questions must necessarily be addressed in the future.

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Photo courtesy of COL (Ret) Elspeth Ritchie, MC, USA

# 2015
# Spurgeon Neel Award Winner

The Army Medical Department Museum Foundation sponsors the Spurgeon Neel Annual Award competition for the best original article that best exemplifies the history, legacy, and tradition of the US Army Medical Department. The following article by Gwyneth Milbrath was selected as the best submission of the 2015 competition.

# Grace Under Fire: The Army Nurses of Pearl Harbor, 1941

Gwyneth R. Milbrath, RN, MSN, MPH*

ABSTRACT

Objective: Much has been written about the military events of December 7, 1941; however, little has been documented about the nurses' work and experience at Pearl Harbor, Hawaii. The aerial assault on Pearl Harbor was the first time in US history that Army nurses had been on the front line of battle. Nurses quickly triaged and stabilized those who could be saved, and provided compassion and comfort to those who were dying, in an environment where the nurses were unsure of their own survival.

Methods: Traditional historical methods and a social history framework were used in this investigation. Primary sources included oral histories from the US Army Medical Department Center of History and Heritage and the State of Hawaii's website, Hawaii Aviation. Secondary sources included published books, newspaper articles, military websites, and history texts.

Results: Due to the limited bed capacity, Hickam Field Hospital converted to an evacuation hospital. Nurses, physicians, and medical corpsman triaged, stabilized, and transported those likely to survive, while staging the dead behind the building. The emergency room at Tripler Hospital was quickly flooded with patients from the battlefield, but the staff was able to sort patients appropriately to the wards, to the operating room, or provide comfort care as they died. At Schofield Hospital, collaboration between tireless doctors, nurses, and corpsmen was key to providing life-saving surgery and care.

*There wasn't any bickering. There wasn't time. Everybody did their job. We're trained for emergencies. Disasters.*

Lt. Gelane Barron, ANC; Tripler Hospital Emergency Room[1]

Much has been written about the military events of December 7, 1971; however, little has been documented about the Army nurses' work and experience in Pearl Harbor, Hawaii. This paper will describe the role and experience of six Army nurses who were caring for patients at Hickam, Tripler, and Schofield Hospitals on December 7, 1941.

During World War I, the number of nurses in the Army Nurse Corps (ANC) grew from 403 nurses on active duty to 21,480 total nurses serving in the "Great War."[2] This number dramatically decreased during peacetime and the Great Depression which crippled the American economy. At the end of 1941, fewer than 1,000 ANC nurses were on active duty.[3] The few military nurses who were on bases in the United States in the 1940s kept busy by treating communicable diseases and orthopedic injuries from sport or training exercises.[4]

Several young and promising ANC nurses were stationed at Walter Reed Hospital, performing their regular duties as well as helping to recruit other nurses.[5] In early 1941, a notice appeared asking for volunteers to serve abroad in the Philippines or Hawaii. Lt. Pauline Girard, Lt. Monica Conter, and Lt. Kathleen Coberly were looking for opportunities to travel overseas, and volunteered to serve. That summer, they traveled together by train from Washington, DC to San Francisco to await passage to Hawaii on the *USS Mariposa*.[5-7] They arrived in Hawaii on July 11, 1941.[6]

Those nurses fortunate enough to be stationed in Hawaii were enjoying the tropical lifestyle of shorter shifts, days at the beach, and beautiful parties at beachside hotels. Many other Navy and Army nurses arrived in Hawaii throughout 1941 in anticipation of foreign threats in the Pacific. As the war in Europe intensified, more young women became part of the ANC; however, numbers were not yet high enough to meet the potential need should the United States become involved in the war. By

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December 1941, there were 82 Army nurses stationed in Hawaii serving at three Army medical facilities: Tripler Hospital, Schofield Station Hospital, and Hickam Field Hospital.[3] The evening of December 6th, there was an elaborate party at the Officer's Club that many of the nurses attended with their dates.[6-8] Lt. Conter thought the view of the light from the battleships reflecting on the water was "the most beautiful sight she'd seen."[5]

## Disaster Strikes Oahu

At 6 AM on the morning of December 7, 1941, six Japanese carriers positioned 200 miles north of Oahu launched the first wave of 181 planes set to destroy Pearl Harbor.[9] Although there were some early reports of abnormal activity the morning of December 7, the warning signs were unheeded and the US military forces at Pearl Harbor were taken by surprise when the Japanese attacked. The Japanese arrived flying approximately 150 feet over Pearl Harbor, guns blazing, a few minutes before 8 AM that Sunday morning.[9]

Lt. Kathryn Doody lay in bed at the nurses' quarters in Fort Shafter, Hawaii, on the morning of December 7, attempting to get some extra sleep on her day off. The noise was so loud; she thought that one of the volcanoes was erupting. Fort Shafter is located in Honolulu, Hawaii, about 5.5 miles from Pearl Harbor, and was home to Tripler Army Hospital.[10] Meanwhile, Lt. Gelane Barron was already walking to work to begin her shift in the Tripler Emergency Room. Barron noticed the planes and smoke, but assumed, like many others, that the Army and Navy pilots were having maneuvers, or the US B-17 bomber planes scheduled to arrive that day were landing.[1]

North of Tripler in the mountains of Oahu was Wheeler Army Air Field, and Schofield Barracks, home to Schofield Station Hospital. Lt. Mildred Irene Clark, also off duty that morning, was sleeping in the barracks at Schofield. The sound of the planes flying directly overhead was so loud it shook the barracks. She tried to go back to sleep, but realizing something was wrong, she called the operating room (OR) at Schofield to see if they were in need of her services. Lt. Clark was told she and all other surgical nurses were to come to the OR immediately. She was out the door in two minutes, running the eleven-block distance from the barracks to the hospital. "I saw what looked like big oranges on the planes and I could see two men. I don't remember being afraid…they were so close that I could hear them talking on their phones… and they were right down over the hospital."[8]

Lt. Girard was already on duty on the wards at Schofield and had just settled into her daily routine when she heard something crash near the building. She joined the patients out on the porch and could see the low flying planes. "The sergeant standing next to [her] said, 'Ma'am, can't you see the rising sun on those planes?'… You could see the Japanese bowing low and [Schofield] had a big red cross on the building but they were machine gun firing so I shoved everybody into the ward."[7] The Japanese were attacking the military strongholds in Oahu, including Pearl Harbor, Wheeler Air Base, and Hickam Air Base, dropping half-ton bombs and raining down machine gun fire.[11]

Hickam hospital was a brand new, 30-bed facility located adjacent to Pearl Harbor on Hickam Army Air Base. Lt. Monica Conter was one of two nurses on duty at this small facility when the Japanese suddenly attacked the air base. As she was evacuating patients in the elevator from the third floor to the first floor, a bomb hit the Hickam power plant and all the clocks stopped at 7:55 AM.[5] Both Hickam Field and Wheeler Army Field, along with Pearl Harbor, were priority targets for the Japanese. Their aim was to prevent any US fighter planes from defending against the Japanese attack force. Had any US bomber, fighter, or patrol planes been airborne, the primary Japanese aim of destroying the Pacific fleet could have been severely compromised. The Japanese attacked with two strikes about half an hour apart. Both Hickam and Wheeler Air Base suffered heavy damages and casualties during both strikes.[11]

Once military leaders realized what was happening, Tripler, Schofield, and Hickam began to prepare for the incoming casualties. All off-duty staff were called in from their quarters, patients were discharged or moved to make room for the incoming wounded, and additional bed spaces were created wherever there was space. When Lt. Barron walked into the ED at Tripler Hospital, it was already full of patients on litters needing care.[1] Schofield Hospital also had ambulances waiting to unload patients with litters of patients lining the halls outside the operating rooms.[8]

Years later, these nurses would reflect on their level of preparedness for the bombings that occurred that morning. Many nurses were relatively new to military nursing and had never been stationed outside of the United States. Some nurses felt well prepared to handle the challenges of that day, and others managed to adapt quickly to the changing situation and provide high-quality care to the injured soldiers. There was no formal mass casualty training, gas mask training, or basic military training of any sort for the nurses stationed at Pearl Harbor prior to 1942.[1,10] Most nurses arrived at their duty station, were given basic lessons of Army etiquette and a couple hours of orientation to the ward, and were put to work.[1]

The medical and surgical nurses at Tripler and Schofield were not trained for a mass casualty scenario, however, the hospitals were able to create more beds and had a sufficient stockpile of supplies to meet the needs of the patients.[8,10] Field medical officers commanded a field force unit, and each unit had an ambulance assigned that was able to quickly transport patients from the front lines to the hospitals.[8] Despite a lack of training in mass casualty or disaster plans, the Tripler emergency room was able to efficiently triage and stabilize the hundreds of patients arriving from Hickam and Pearl Harbor. "Everybody knew their job. Everybody was trained for warfare and I think we worked very well as a group. There was no panic or anything."[10]

### Hickam Field Hospital

The situation at Hickam Hospital was much more chaotic than Tripler Hospital due to drastic differences in staffing, resources, and capacity. The Hickam nurses, corpsmen, and physicians were frantically trying to handle the hundreds of casualties on their front lawn with only the resources and space to care for 30 patients. Hickam Hospital had only been open for three weeks, and the few nurses trained to staff the hospital were still unfamiliar with the facility. Many of the beds were still missing a mattress, and only the third floor was set up for inpatient care. All patients were evacuated to the first floor where they believed they would be safer from the bombings.[5]

After the first wave of bombing ended, the casualties began to pour into Hickam hospital. The barracks had been heavily bombed and collapsed during the attack, killing and wounding the many soldiers that were still in their rooms. Patients from the barracks had terrible crush injuries and wounds contaminated with the dust and debris from the building collapse.[5] Three additional nurses, including Chief nurse Annie Fox, arrived to assist the two nurses who were struggling to manage the unimaginable influx of patients. The wounded soldiers and civilians arrived at Hickam in ambulances, Coca-Cola trucks, laundry trucks, private vehicles, and anything else that was available.[1,6] Patients were triaged as they arrived at the hospital; those still living were placed on the ground along the porch, and the dead and mortally wounded were placed behind the hospital. The nurses began stabilizing and comforting the hundreds of patients at their door as quickly as they could.[5]

"We would just go down that porch giving [morphine] shots and trying to stop the hemorrhaging and the pain on that outdoor porch with people lined up. We would give it just as fast as we could… It was a thing to do in an emergency, which is an understatement. Just going down the porch giving those 10 shots with a 10cc syringe… We went in to fill up and came back out where we left off and gave more…that's how I reacted and everybody else was doing it. That was the only thing we knew to do in the middle of all of this. We hoped we were saving their lives, keeping them from pain, and maybe stopping some of the hemorrhaging."[5]

In total, 139 soldiers were killed and 303 were wounded at Hickam Air Base, and the vast majority of these casualties would have stopped for treatment at Hickam Hospital.[12] Anticipating that Hickam would become completely saturated with severely wounded soldiers, Major Frank H. Lane, commander of Hickam Field Hospital, wisely decided to convert Hickam into an evacuation hospital, keeping only the "walking wounded," and transferring all other cases to Tripler or the civilian Queen's Hospital in Honolulu.[6,13]

### Tripler Hospital

At Tripler Hospital, the staff in the emergency room quickly triaged, stabilized, and admitted all the Soldiers coming from Hickam Field as well as some Navy Sailors from Pearl Harbor. Those that were dead or mortally wounded were sent to a temporary morgue located behind the hospital. Patients were then prioritized based on who needed immediate surgery that day, those who could wait until a later date, and those who could go directly to the wards. The emergency nurses continued to give the patients injections of morphine and tetanus in a similar fashion as those at Hickam. They marked their foreheads with an M or a T to document who had received these medications.[1]

Tetanus and other infections were a chief concern of those providing wound care; however, inside the war zone sterility was not always possible. Despite using the same needle on multiple patients, no infections were reported.[1,5] All soldiers would have received a tetanus immunization prior to entering the combat zone, and those with injuries from shrapnel, bullets, or other metals were given a booster vaccine. There were no deaths due to tetanus reported in Pearl Harbor. The addition of sulfa drugs in wound care drastically decreased mortality rates from infection in World War II compared to World War I. Oral sulfa therapy was administered both pre- and postoperatively. Every soldier carried a packet of sulfa drug and was instructed to take it orally as soon as he was wounded.[14]

Despite the fear and uncertainty that most felt on December 7, 1941, medically trained and untrained people quickly arrived at Tripler to help manage the overwhelming number of casualties. Civilian volunteer nurses were automatically inducted into the ANC, and those off duty

reported immediately to help.[1] Coincidently, there was a physicians' convention in Honolulu that weekend, and the speaker for the morning of the bombing was delivering a lecture about war casualties. "…In the middle of this lecture, word went out to the auditorium where they were, all available doctors to report to Tripler Army Hospital…we got lots and lots of civilian doctors that day."[10] Another surgeon had presented a new way to locate shrapnel, and was able to use this method on many of the injured soldiers.[1] A total of ten additional physicians and six additional surgeons reported to Tripler to assist with the many casualties.[15]

Many patients were received at Tripler with gaping wounds. Fragment wounds required immediate surgery and were sent to the operating room where Lt. Doody had just arrived and was preparing to assist as a circulating nurse in the OR.[1,10] She scrubbed to prepare to enter the sterile operating room, she could see three patients sharing the operating room. Patients often could not be moved onto the operating tables, and their surgery was performed on the litter used to transport them into the hospital from the warzone.[10]

### Schofield Station Hospital

The operating room at Schofield Station Hospital was just as busy as Tripler. Most of their patients had arrived from the nearby Wheeler Field Air Base, and had severe abdominal wounds and mangled arms and legs requiring amputation. ANC nurse Lt. Clark immediately began to prepare the most critical patients for surgery. As one of only two nurse anesthetists at Schofield that day, Lt. Clark could not manage all the preparation and intraoperative sedation alone. When she arrived, there were approximately 30 patients lined up along the hallway outside the OR for surgery. Volunteer physicians helped with anesthesia by giving IV anesthetics, spinal blocks, and administration of blood products; however, only those specially trained in anesthesia were able to give inhaled anesthetics. Lt. Clark described her overall experience that day as extremely efficient. Nurses and physicians worked together as a team with some physicians prepping patients for surgery while others operated. Lt. Clark used her nursing expertise to prepare her patients both physically and spiritually for surgery. In addition to providing important therapies, she spent time talking and praying with her patients. She wanted to meet any needs her patient may have had, not just medical needs.[8]

The medical knowledge at the time understood shock as failure of the peripheral vascular system resulting in inadequate circulation. This could be caused by loss of one to two quarts of blood; resulting in pallor, mental status changes, gasping respirations, increased heart rate, and a profound drop in blood pressure. Shock was prevented through controlling bleeding, immobilizing fractures to prevent further bleeding from movement, and warming the body with blankets and warm oral fluids. Pain control was also an important tenant of shock prevention. Pain was understood to worsen shock, so morphine was given not only to relieve pain, but also to improve a soldier's chances of survival. Morphine was given intramuscularly in doses of a quarter to half grain, or 15-30 mg. If a Soldier were showing early signs of shock, he would be positioned with his legs above his head and given oral fluids immediately unless he needed an emergent operation. Solutions with 3%-5% glucose or 0.9% sodium chloride were given either subcutaneously or, preferably, intravenously. Intravenous (IV) fluids were preferred because glucose solutions could provide some nourishment and the fluids aided in stimulating the kidneys to remove toxins from the body. However, soldiers with massive bleeding saw only temporary improvement from IV fluid administration because the solution would quickly leave the peripheral vascular system. For soldiers suffering from severe shock, blood products including fresh whole blood or blood plasma were key in preventing death from shock and massive hemorrhage. The technology of "banking" blood products was newly introduced during this period, allowing blood and plasma to be safely stored up to 8 days prior to administration.[14] Many injured soldiers on leave donated blood to "repay" the blood bank for blood they had received during the Pearl Harbor attacks.[16]

On the wards at Schofield Station Hospital, Lt. Girard prepared for the influx of patients by moving all of the hospital beds from the exterior porch and into the middle of the large ward. The patients on the convalescent wards all requested to be discharged so they could go to war. Patients arrived in the ward and again required triage; some went to the OR, others to the morgue, and some stayed for wound care and to await surgery at a later date. On many wards, the physicians were unable to examine the patients until that evening because they were busy stabilizing patients in and around the operating room, leaving the ward under the sole care of the nurses. By the time the physicians had arrived on the ward, the patients were all undressed, sorted, assessed, and stabilized by the nurses and corpsmen.[7]

### Trauma Care at Pearl Harbor

For those Army Soldiers killed or injured, the primary mechanism of injury was the blast force and debris from the bomb, or crush injuries from structural collapse. The majority of injuries seen from an aerial bombardment consisted of multiple fractures, hemorrhage, and extensively torn muscles, with many of those injured rapidly

progressing into shock. The detonation of the half-ton bombs caused the steel jacket to be blown into small, sharp fragments at a high enough velocity and rotational force to carry them over 1500 yards. The combination of the forward and rotational momentum caused severe damage to the human tissue and bone with little external evidence of injury, with an estimated one-third of those wounded suffering mortal injuries. Those standing upright during the blast were most likely to be injured, with wounds to the legs being most common. The recommended treatment was to splint any fracture or suspected torn muscle, provide warm blankets, sedate with morphine, and rest. Those incurring more serious injuries involving the abdomen or chest would receive surgical treatment immediately with the goal of minimizing organ damage and internal bleeding.[14]

Crush injuries and compound fractures were common injuries among the Soldiers in Hawaii. Crush injuries were treated by immediately compressing the effected tissue with an elastic bandage with approximately 40-60 mm Hg of pressure. This would compress the tissue enough to decrease swelling, but would allow for blood flow to the injured tissue, preventing gangrene. Compound fractures were best treated in the operating theater; however, initial treatment involved splinting the affected bone, reducing the fracture if possible, applying sulfonamide powder to the wound, and covering with a dressing. Under normal circumstances, compound fractures are a high priority for surgery; however, due to the large number of critical cases, most orthopedic repairs had to wait 24-72 hours. Despite this delay in treatment, no cases of gas gangrene or deaths from other infection occurred, which was a highly significant improvement in medical and surgical treatment compared to World War I.[14]

Wound care at the time heavily emphasized protection from bacteria and bleeding control. Bullets from the air strike were fired at an extremely high velocity, causing the entrance wounds to appear small, and exit wounds would be several times larger.[7] Direct pressure was applied for 2-3 minutes before bandaging to control bleeding. For most wounds, nurses would apply a pressure dressing using a dry, sterile dressing; a freshly-ironed handkerchief; or a clean towel. If a pressure dressing was inadequate to control the bleeding, a tourniquet was applied to either the upper arm or thigh with enough pressure to compress the artery against the bone. The tourniquet was loosened every 30 minutes to reassess the wound for bleeding. If the bleeding was controlled, direct pressure to the wound and a pressure dressing could be applied, restoring blood flow to and from the injured extremity. Wounds were not routinely irrigated due to the risk of re-bleeding; rather they would sprinkle 3-10 grams of sulfadiazine into the wound, cover it with a dressing, and await surgery if needed.[14]

Other advances in wound care included packing and dressing wounds instead of closing them with sutures. This allowed the sterile packing material to absorb infectious drainage from the wound and decreased the incidence of wounds colonized with anaerobic bacteria, including the often fatal gas gangrene. There were only 15 cases of gas gangrene from Pearl Harbor, all from wounds prematurely closed with sutures.[14]

## Collaboration and Dedication

Soldiers and medical personnel reacted both positively and negatively to the enormous amount of physical, mental, and emotional stress experienced during and following the Pearl Harbor bombing. Generally, patients, volunteers, and staff had a positive attitude and were ready to help the efforts at Tripler, Schofield, and Hickam.[7] Officers' wives, Red Cross volunteers, civilian nurses and doctors, patients, and even prostitutes came to the hospitals to volunteer. At Tripler and Schofield, untrained volunteers assisted the effort by making 2x2 and 4x4 dressings, cotton balls, and swabs out of the bolts of gauze at the hospital; as well as cleaning, sterilizing, and preparing the instruments in the OR at all hours of the day and night.[1,8,10] In Schofield, those patients almost ready for discharge volunteered by bringing sterile solutions to the OR. Lt. Clark later reflected that "everyone worked so well and functioned such as [she had] never seen, truly a team. They knew what to do. They knew how to do it."[8] Patients and officer's wives also volunteered at Hickam to make dressings for Soldiers, even arriving in the middle of the raid to help.[5]

The physicians, nurses, medical corpsman, and volunteers worked together many hours past their shifts to ensure all of the patients were well-cared for, despite being understaffed and having no breaks. Lt. Girard recalls, "no one had to ask you to stay on. You just stayed on until your work was done…In the service, if you're needed, you're there. We don't have to worry about overtime, that's your job. We can work 10, 12, 14 hours and think nothing of it because [there] was something to be done."[7] Following the Pearl Harbor attack, Lt. Barron and two other nurses covered the Tripler emergency room for a 20-hour shift.[1] Nurses who had worked the night before stayed on until the afternoon, only to sleep and return less than eight hours later. In the OR at Schofield, Lt. Clark did not take a break until 6 PM that evening, and stayed on until 4:30 AM, only to start more cases early the next morning.[8] In many ways, the United States was unprepared and surprised by the attack on Pearl Harbor; however, the doctors and nurses

working in the Army facilities in Hawaii were able to swiftly care for the injured soldiers. "It was just a marvelous thing how they handled the emergency. We saved lives. It was something…They were just tremendous, and deserved to be recognized for their extraordinary work and efficiency."[8] The staff was able to put their own personal fears and fatigue aside, work together as a team, and take care of patients without complaint. The health care team was united under the common cause of saving the lives of the Soldiers who had sacrificed themselves for their country.[7,8,10]

In many ways, the United States was unprepared and surprised by the attack on Pearl Harbor; however, the doctors and nurses working in Hawaii that day were able to swiftly care for the injured Soldiers. In an interview 40 years after the bombing, Clark shares her reflections about that day. "It was just a marvelous thing how they handled the emergency. We saved lives. It was something…They were just tremendous, and deserved to be recognized for their extraordinary work and efficiency."[8] The staff was able to put their own personal fears and fatigue aside, work together as a team, and take care of patients without complaint. The health care team was united under the common cause of saving the lives of the soldiers who had sacrificed themselves for their country.[7,8,10]

The intersection of duty, resilience, and compassion shaped the nurses' work at all three facilities, and their story is a testament to their dedication to others. The nurses serving in the Army hospitals at Pearl Harbor played a significant role in the opening hours of the Japanese attack in 1941. Through triage, collaboration, stabilization, compassion, and dedication, they saved hundreds of lives.

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# 2015
# Spurgeon Neel Annual Award Runner-up

The Army Medical Department Museum Foundation sponsors the Spurgeon Neel Annual Award competition for the best original article that best exemplifies the history, legacy, and tradition of the US Army Medical Department. The following article by Dr Justin Barr was selected as the second best submission of the 2015 competition.

# Military Medicine of the Russo-Japanese War and its Influence on the Modernization of the US Army Medical Department

Justin Barr, MD*

In 1905, Japan shocked the world by becoming the first Asian nation to defeat a western country on the field of battle since Genghis Khan and the Mongols. They simultaneously commanded the attention of the military medical community by claiming to be the first combatant force to suffer fewer deaths from disease than from enemy action. Given the recent, disease-ridden medical debacle of the Spanish-American War, American military medical reformers used Japan's achievements as a model for the US Army Medical Department (AMEDD) to emulate.[1] After briefly defining Japan's said success, this essay reviews the failures of the AMEDD in the Spanish American War. It then highlights how Japan, fighting less than a decade later, appeared to achieve dramatically different results. I conclude first by proving Japan's medical victory fictitious and then by showing how AMEDD reformers nonetheless used the narrative of success to advance their own agenda in modernizing the department.

## Japan's Success and America's Failure

Japan and her supporters proudly trumpeted its success controlling disease. Their victory on the field of battle was evident, driving the Russians out of Korea and Manchuria and claiming the territory for themselves.[2] Their conquest over disease appeared equally obvious: Japan lost more men to battle than to disease. Numbers vary based on source consulted, but whereas 53,000-59,000 men died from direct enemy action, only 12,000-27,000 men died from illness.[3] While Japan and its allies claimed priority for this achievement, in fact the Prussians obtained a similar ratio 30 years earlier in the Franco-Prussian War.[4] Nonetheless, compared to most 19th century wars where disease far outstripped combat deaths, Japan seemed to accomplish a monumental feat. (America, for example, did not achieve similar results until World War II.) Figure 1 shows the number of disease deaths per battle death in wars of the 19th century. The graph highlights Japan's apparent success, and it was to graphs and comparisons of this type that Japan and her supporters pointed. Reality, as this essay will prove, was more complicated.

If the Russo-Japanese War was championed as a poster-child of military medical efficiency, the Spanish American War represented its alleged nadir. As Figure 1 also demonstrates, far more Soldiers died from disease in that conflict than from direct contact with the enemy.[6] Combat medicine acquitted itself well, applying the germ theory of disease through antiseptic dressings and deploying new technology like x-rays to manage the combat-wounded; the died-of-wounds rate dropped from 17% in the Civil War to 4%. However, sanitation and public health failed the American Soldier. Bivouacked in camps that paid little heed to waste management, thousands of Soldiers suffered—and died—from diarrhea, 74% of which resulted from typhoid.[7] Until Walter Reed's team proved the role of the mosquito as a vector for yellow fever, that disease ravaged US service members as well.[8] American volunteers who never left the United States also suffered grievously, as camps like Chickamauga became synonymous with death from diarrhea.[9] All told, over 2500 men died from disease, compared to 385 from combat.[10]

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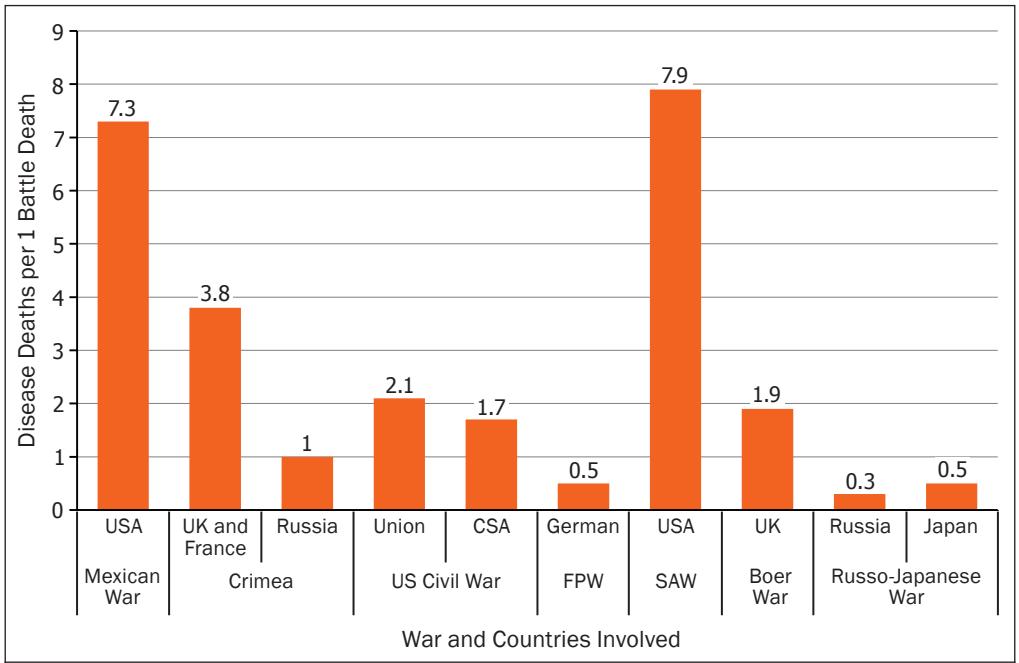


Figure 1. Disease deaths per battle deaths by 19th century war and combatant, showing the apparent success, though not priority, of the Japanese.[5] FPW indicates Franco-Prussian War; SAW, Spanish American War; UK, United Kingdom; CSA, Confederate States of America.

The debacle of American military medicine in the Spanish American War spawned reform efforts in the Army Medical Department. In the immediate post-war years, searing public commentary led to the Dodge Commission investigating the reasons behind the failure of the Army and its medical support. Presented in February of 1899, the Report delivered a fair, impartial accounting. Surgeon General William Sternberg and the AMEDD escaped most of the blame, with responsibility assigned to Congress for not funding the department adequately and restricting the number of regular Army physicians.[11] This deficiency represented a general problem in the US military, with poor relations between line and staff officers; the two groups failed to work together in war, an issue not totally resolved until the Elihu Root's restructuring of the Army.[12] The Army kept enough line officers to command a 100,000-man army; however, it retained enough surgeons for only for 42,000 men.[13] Contract surgeons hired to make up the difference had little experience in public health, contributing to the deadly diarrheal epidemics. Effective as physicians, they failed as military medical officers.[14] Military surgeons from Sternberg on down wanted Congress to fund a reserve corps of Army doctors that would allow better trained Army physicians to deploy in time of war.[15] They introduced multiple congressional bills demanding a larger, better trained cadre of uniformed physicians.[16]

AMEDD reformers used the apparent success of the Japanese to promote their agenda and provide evidence for the importance and efficacy of their suggested changes. "Other nations, including so poor a nation as the Japanese, are willing to pay the cost of increased efficiency in the shape of a large and well organized medical service," noted Army Surgeon General Robert O'Reilly, implying that America should as well.[17] Even outside military medicine, American Medical Association President William Mayo used the success of the Japanese as a fillip to improve civilian public health in this country.[18] By 1907, The Surgeon General's Index contained almost 500 articles on the Russo-Japanese war, highlighting the attention it received in the medical community.

No one lionized the Japanese more than Louis L. Seamen. Having served as a volunteer surgeon in the Spanish American War, Seaman travelled to Manchuria as a quasi-official medical attaché to the Japanese during their war with Russia. He returned to publish gushing accounts of their ability to control disease.[19] Seaman explicitly strove to force change in the AMEDD, dedicating his 1907 book: "To the Medical and Sanitary Officers of the Japanese Army, who have proved that the normal condition of the Soldier is health…; to that vast army of American Dead, whose lives in war have been needlessly sacrificed through preventable diseases, ignorance, and incompetency."[20] He and others pointed to the sufficient number of Japanese medical officers, their training, and most importantly, their effective integration with line officers that allowed them to effect necessary public health measures, all features deemed lacking in the AMEDD.

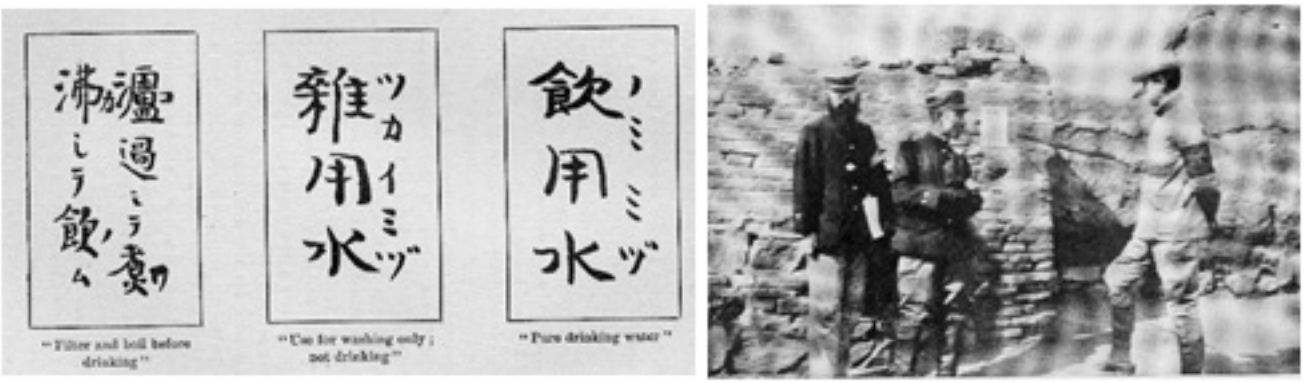


Figure 2. Left: signs posted at water sources in Japan indicating water purity. Right: an American attaché points to one such sign posted at a well.

Part of the western acceptance of Japanese medicine stemmed from its adoption of modern germ-based medicine. Early Portuguese and Dutch traders to Japan contributed little medical knowledge, but the opening of Japan by Commodore Matthew Perry and especially the Meiji Restoration of 1868 provided an institutional and intellectual framework for western medicine to take hold.[21] As Germany dominated medical research in the late 19th century, Japan emulated the Teutonic system. German professors like Karl Leopold Mueller travelled to Japan to establish a medical education system. Stellar Japanese students studied and worked in German laboratories. Kitasato Shibasaburo, perhaps the best known Japanese scientist, studied with Robert Koch, produced the first pure tetanus bacilli in 1881 and, along with Behring, proved the efficacy of the diphtheria antitoxin.[22] He became world famous, sharing the star-billet with Joseph Lister at an 1891 London conference. Kitasato and colleagues like Ogata Masanori, who also studied with Koch and Max Petternkoffer, brought the gospel of bacteriology back to Japan, where it was widely accepted.[23]

Military medical officers applied this bacteriology to their public health efforts in the Russo-Japanese War. Efforts started in training camp, where the Japanese Surgeon General distributed pamphlets to each recruit instructing them to cook their food thoroughly, boil their drinking water, seek medical care early, and avoid contact with rats, fleas, and mosquitoes.[24] These pamphlets explicitly based their recommendations on the germ theory of disease imported from Germany. The flyers also instructed Soldiers to keep themselves clean, and here the Japanese propensity for bathing greatly assisted in camp hygiene.[25] This educational effort continued overseas, with medical officers delivering regular lectures to reinforce these concepts.[26]

In addition to (and arguably more important than) their role in treating combat wounded, Japanese medical officers at the front carried important public health responsibilities.[27] Physicians accompanied foraging parties to check food quality; they inspected provisions; they established and monitored sewer and latrine systems in the camp; and when the Japanese captured a town, medical doctors accompanied some of the first troops occupying the village to ensure sanitation prevailed. They performed their jobs effectively because of their acceptance by line officers as subject-matter experts whose advice was to be heeded. This respect reflected Japan's adoption of the Prussian Staff system, with its elevation of staff officers to a position equal to that of the line.

Japanese physicians' most important task lay in maintaining a potable water supply.[28] Per Surgeon General Shigemichi Suzuki, "the paramount importance of good water supply in military sanitation was recognized… drinking unboiled water was strictly forbidden even in peace time and this rule was strenuously applied in the late war."[29] The Japanese custom of tea consumption helped ensure boiled water.[30] Medical officers also regulated well-water quality. When they came across a new water source, they used their bacteriology-based laboratory training to test its contents and regulate its use (see Figure 2).[31] American reformers recognized the importance and proper emphasis on public health in the Japanese Army. Colonel John Hoff believed Japan's success stemmed solely from the "observance of well-established hygienic rules [and] proper sanitary organization…this war has developed nothing new in medical treatment or surgical technique, its one lesson for us is summed up in a single word: *prevention* [emphasis original]."[32]

The Japanese might have achieved greater success had they vaccinated their troops. Almroth Wright developed the typhoid vaccine in 1897. It was available to, but not mandatory for, the British Army during the Boer War.

About 5% of British Soldiers chose to be vaccinated; thousands of others perished from the disease.[33] Given the impact of disease in the Spanish American and Boer Wars, typhoid commanded substantial attention in the military medical literature.[34] Articles variously supported and decried vaccination.[35] The Japanese opposed it, with Surgeon General Suzuki categorically stating that "preventive inoculations were not performed…preventive inoculation for typhoid fever, dysentery, cholera, and plague not yet being certain."[36] Eschewing the cholera vaccine had minimal impact on their forces.[37] They did mandate smallpox vaccinations and as a result suffered only 209 cases with 12 deaths from the disease.[38] Based largely on the experience of the British and Japanese, the US Army became first to mandate typhoid vaccination in 1911.[39]

While the Japanese achieved measureable success against water-borne pathogens, their rations, specifically white rice, resulted in tens of thousands of unnecessary casualties. Beriberi had bedeviled Asian societies for centuries. By the late 19th century, a fierce etiological debate traversed Europe and Asia, with apostles of bacteriology claiming to identify a causative microorganism whereas other scientists insisted on a nutritional deficiency. (In 1896**,** Christiaan Eijkman proved the disease resulted from the lack of vitamin B1, though it took decades for his hypothesis to gain acceptance).[40] Polished, white rice lacks vitamin B1; it was also more expensive and thus a status symbol in Japan. As such, for much of history only upper-class Japanese suffered from the disease. The Army and Navy, trying to elevate social position of soldiers and sailors, transitioned to polished, white rice in the late 19th century only to see the incidence of beriberi soar among their forces. Without identifying the precise etiology, the Japanese Navy recognized the correlation between white rice and the disease, added barley to their rations in 1886, and effectively eliminated the problem. The Japanese Army, however, remained wed to an infectious etiology and did not alter their rations until February of 1905.[41] By then, over 80,000 Japanese soldiers required evacuation from the theater for beriberi; around 10,000 of those men died.[42]

## Conclusions: Varying Definitions of Success

The Japanese recognized and touted their military medical accomplishment. They claimed their ability to control disease was an essential factor in their victory over the numerically superior Russians:

> Russia may be able to place 2,000,000 men in the field. We can furnish 500,000. You know that in every war four men die of disease for every one who falls from bullets. That will be the position of Russia in this war. We propose to eliminate disease as a factor. Every man who dies in our Army must fall in the field of battle. In this way we shall neutralize the superiority of Russian numbers and stand on a comparatively equal footing.[43]

In fact, Russian forces in theater did not outnumber the Japanese, and the Russians achieved similar success in controlling disease. Yet the continued *perception* of Japanese success not only elevated Japan's standing among modern nations but also served as evidence for American military medical reformers. The conclusion of this article examines Japan's claims of medical superiority—and finds them wanting—while simultaneously demonstrating how Americans like Seamen used the notion of Japanese superiority to effect real change in the AMEDD.

While the Japanese undeniably lost more men to battle than to disease, a more sophisticated analysis of their casualty statistics undermine their claims of military medical superiority. Biostatistics as a field was just emerging in this era, with leaders like Karl Pearson, Francis Galton, and Charles Davenport, later infamous for their work on eugenics, devising and publishing powerful new methods of analyzing numerical data in their new, 1901 journal *Biometrika*.[44] Applying even rudimentary biostatistics shows that the disease death:battle ratio is a poor metric for capturing the efficacy of a combatant's medical service and leads to inaccurate conclusions when comparing one war against another. First, it does not account for either the size of the army or the length of the war. Reassessing Japan's losses from disease while taking into account these variables reveals a notable lack of distinction. As Figure 3 shows, Japan lost proportionately the same number of men from disease as other 19th century combatants.

Secondly, the ratio ignores differences in battle deaths among wars, the crucial denominator in this fraction. The relative sanguinity of a conflict could make 20,000 deaths from illness appear as either a disaster or triumph of military medicine. The high number of casualties the Japanese suffered offset their losses from sickness. Almost 60,000 Japanese Soldiers and sailors died from battle wounds, a rate of 54 deaths per 1000 men per year. As Figure 4 shows, this rate was higher than all other 19th century military engagements except for the Crimean and Franco-Prussian Wars.

The specific character of fighting in the Russo-Japanese War led to this high casualty rate. The combat forecast the trench warfare of World War I, with the Russians often occupying a fixed defensive position complete with water cooled machine guns, barbed wire-laced

fortifications, and modern, quick firing artillery batteries.[45] Japan assaulted across no-man's-land in rigid, Prussian formations, taking thousands of casualties. Even Ian Hamilton, a British military attaché to the Japanese who later commanded the disastrous landings at Gallipoli, reported "the Japanese are lavish with their brave infantry, and think little of losing two or three hundred men."[46] The profligate casualties skewed the ratio of disease deaths:battle deaths and made Japanese military medicine appear more effective than it actually was.

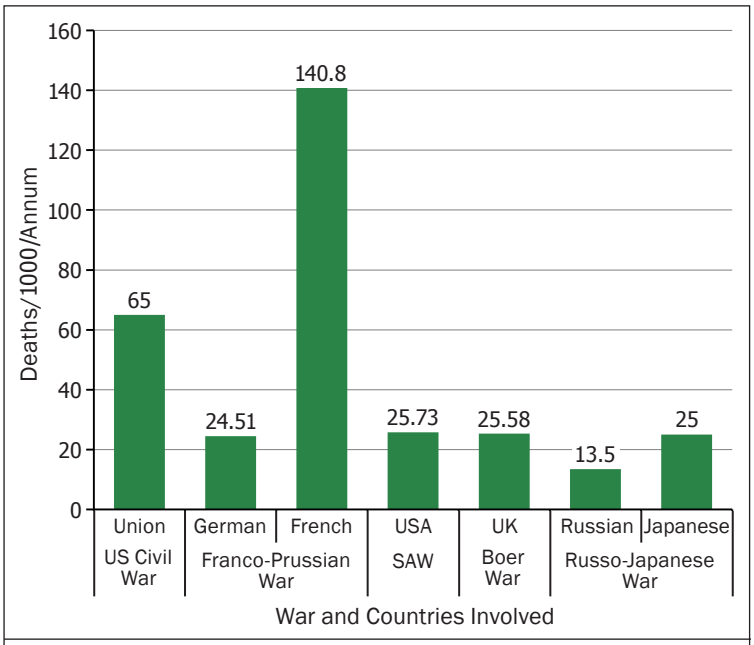


Figure 3. Death rates per 1000 men in the Army per year, demonstrating Japanese equivalence to other 19th century combatants, including the US Army in the Spanish American War. SAW indicates Spanish American War; UK, United Kingdom.

Perceptions matter as much as reality in history, and the *perceived* notion of Japanese success following American failure helped catalyze reforms of the AMEDD.[47] Seaman certainly propagated this mantra of Japanese superiority, reporting numbers highlighting their achievement. Not all of Seaman's contemporaries accepted his statistics even when they agreed with his overarching goal of AMEDD reform. Charles Stokes, the Surgeon General of the American Navy at the time, commented, "Dr. Seaman, whose aims seem perfectly proper, can do the cause of military surgery and military sanitation in this country no greater service than that of correcting his statistics and removing the wrong impressions some of his remarks have made."[48] And Lewis Duncan later published an exhaustive review of casualty statistics in part to counter the "ridiculously false idea that the Americans in Spanish American War lost fifty-six times as many men by disease, proportionally, as the Japanese in their recent war."[49] Despite some countervailing views, the trope of Japanese success persisted (and has endured into the present).[50]

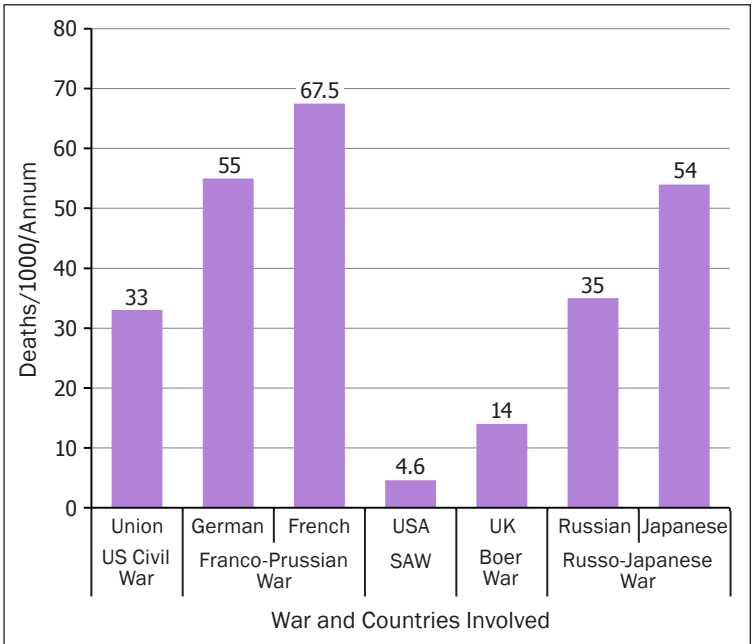


Figure 4. The rates of combat deaths, elucidating the high relative casualty rate suffered by the Japanese. SAW indicates Spanish American War; UK, United Kingdom.

The AMEDD successfully used this narrative to foster multiple reforms in the early 20th century. A 1901 reorganization of the AMEDD stemmed from deficiencies in the Spanish American War but failed to address numerical shortages and especially relations with the line.[51] Japan's apparent achievements in 1904-1905 provided new ammunition for reformers. With figures like Rough Rider Teddy Roosevelt arguing for the AMEDD in front of Congress, the legislative body added 123 billets to the department in 1908. A reserve medical corps was established to avoid again relying on untrained contract surgeons.

Japan's demonstration of the importance of sanitation to preserving their fighting force led to public health instruction for line officers. In 1905, the Secretary of War established a department of military hygiene at the United States Military Academy at West Point.[52] In 1907, both the Army Staff College and the Army War College initiated courses on sanitation.[53] These moves reflected military recognition of the salience of public health

measures and further elevated the stature of uniformed physicians as specialists and equals who could provide the expertise necessary to keep an army intact.

These reforms contributed to the marked success of the AMEDD in World War I where the American Expeditionary Force managed to limit deaths from disease to fewer than those from combat.[54] Victor Vaughan, who, along with Walter Reed had investigated the typhoid outbreaks at Chickamauga and again donned a uniform in 1917, remarked: "I served in the war with Spain in 1898, and I went time and again to a division officer and made certain requests or offered certain advice. As a rule, I was snubbed…but in the late war [World War I] I had a different experience. I never went to a line officer with a recommendation but that he said, 'Doctor, it will be done.'"[55] The perceived and propagandized ability of Japanese medical officers to protect troops led to reforms in the US Army and AMEDD that provided the foundation for this change in attitude and change in care, as uniformed American physicians could now fulfill their duty to preserve the fighting force.

## Endnotes

1. British military medical reformers, embarrassed after the disease-ridden Boer War, did the same. See Claire Herrick, "The Conquest of the Silent Foe': British and American Military Medical Reform Rhetoric and the Russo-Japanese War," in *Medicine and Modern Warfare*, edited by Roger Cooter, Mark Harrison, and Steve Sturdy, 99-130 (Atlanta: Rodopi, 1999).
2. The best single volume history of the Russo-Japanese War remains Dennis and Peggy Warner, *The Tide at Sunrise: a History of the Russo-Japanese War* (New York: Charterhouse, 1974).
3. For 53,000 battle deaths and 12,000 disease deaths, see Louis Livingstone Seaman, *The Real Triumph of Japan: the Conquest of the Silent Foe* (New York: D. Appelton and Co., 1907) 510. For 59,000 and 27,000, see Louis C. Duncan, "The Comparative Mortality of Disease and Battle Casualties in the Historic Wars of the World," *Journal of the Military Service Institution of the United States* 54, no. 188 (1914): 172.
4. Roger Cooter, "Of War and Epidemics: Unnatural Couplings, Problematic Conceptions," *Social History of Medicine* 16 no. 2 (2003): 292. Duncan, "The Comparative Mortality of Disease and Battle Casualties in the Historic Wars of the World," 169.
5. M. R. Smallman-Raynor and A. D. Cliff, *War Epidemics* (Oxford: Oxford University Press, 2004).
6. For the best history of military medicine in the Spanish American War, see Vincent J. Crillo, *Bullets and Bacilli: The Spanish-American war and Military Medicine* (New Brunswick: Rutgers University Press, 2004). For coverage of the Philippines theater, see Warwick Anderson, *Colonial Pathologies: American Tropical Medicine, Race, and Hygiene in the Philippines* (Durham: Duke University Press, 2006), chapters 1 and 2. For an overview of the AMEDD in this era, see Mary C. Gillet, *The Army Medical Department 1865-1917* (Washington DC: Center of Military History, 1995) chapters 5-11. J. T. H. Connor, "Before the World in Concealed Disgrace,' Physicians, Professionalization and the 1898 Cuban Campaign of the Spanish American War," in *Medicine and Modern Warfare*, edited by Roger Cooter, Mark Harrison, and Steve Sturdy, 29-58 (Atlanta: Rodopi, 1999).
7. Crillo, *Bullets and Bacilli*, 138.
8. For a recent study examining the role of Yellow Fever in the Spanish American War, see Espinosa, Mariola. *Epidemic Invasions: Yellow Fever and the Limits of Cuban Independence, 1878-1930* (Chicago: University of Chicago Press, 2009). Multiple works have examined Walter Reed's efforts, including: Howard A. Kelly, *Walter Reed and Yellow Fever*, 2nd ed. (Baltimore: The Medical Standard Book Company, 1906) and John R. Pierce and Jim Writer, *Yellow Jack: How Yellow Fever Ravaged America and Walter Reed Discovered Its Deadly Secret* (New Jersey: John Wiley & Sons, 2005).
9. Connor, "Before the World in Concealed Disgrace," 36-37.
10. "America's Wars," http://www.va.gov/opa/publications/factsheets/fs_americas_wars.pdf (accessed 27 September 2015).
11. The AMEDD's lack of control over supplies also damned their effort to provide adequate care. Stephen C. Craig, *In the Interest of Truth: the Life and Science of Surgeon General George Miller Sternberg* (Fort Sam Houston: Borden Institute Press, 2013) chapter 12. Cirillo, *Bullets and Bacilli*, chapter 5.
12. Russel F. Weigley, *History of the United States Army* (New York: MacMillan, 1967).
13. Major W. C. Borden, "Minutes from the meeting of The Association of Military Surgeons," *Journal of the Association of Military Surgeons*, Vol. 17 (1905-06): 530.
14. Anderson, *Colonial Pathologies*, 30-32.
15. "Letter from George Sternberg to the Adjutant General of the Army," *Journal of the Association of Military Surgeons* XIII (1903-04): 325-27. Azel Ames, "A Medical Reserve Corps for the Army of the United States," *Journal of the Association of Military Surgeons* XVI (1904-05): 69-94. "Army Medical Reorganization," *Journal of the Association of Military Surgeons* XVI (1904-05): 63.
16. See, for example, "Bill for the Increase of the Medical Department of the Army," *Journal of the Association of Military Surgeons* XII (1903-1904): 327-330.

17. Quoted in Bobby A. Wintermute, *Public Health and the U.S. Military: a History of the Army Medical Department, 1818-1917* (New York: Routledge, 2011) 158. See also Jefferson Randolph Kean, *Journal of the Association of Military Surgeons* XVIII (1905-06): 1-35.

18. William J. Mayo, "The Medical Profession and the Issues Which Confront It," *Journal of the American Medical Association* XLVI, no. 23 (1906): 1737-1740.

19. Publications include: Louis Livingston Seaman, *Shall Disease Triumph in Our Army? A Plea for Recognition of the Medical Department of the United States Army* (New York: American Defense Society, Inc, 1904). Seaman, From Tokyo Through Manchuria with the Japanese. Seaman, "Observations in the Russo-Japanese War." Louis Livingston Seaman, "The Real Triumph of Japan or the Conquest of the Silent Foe." *Journal of the Association of Military Surgeons* 17 (1905-06): 500-30. Seaman, *The Real Triumph of Japan*. Louis Livingston Seaman, "The Prevention of Disease in the War: More Power for the Medical Department of the Army," Pamphlet No. 25. (New York: American Defense Society, Inc., 1918). Louis Livingston Seaman, "Some of the Triumphs of Scientific Medicine in Peace and War in Foreign Lands, with Suggestions upon the Necessity of Important Changes in the Organization of the Medical Department of the United States Army." (New York: A.R. Elliot Publishing Company, 1908).

20. Seaman, *The Real Triumph of Japan*, opening dedication.

21. Harold Cook, *Matters of Exchange: Commerce, Medicine, and Science in the Dutch Golden Age* (New Haven: Yale University Press, 2007) chapter 9. Andrew Gordon, *A Modern History of Japan: from Tokugawa Times to the Present* (New York: Oxford University Press, 2003) 61-76. Albert Craig, "The Central Government," in Marius Jansen and Gilbert Rozman, eds, *Japan in Transition* (Princeton: Princeton University Press, 1986) 36-67.

22. Anna Jannetta has recently complicated this simplistic periodization by carefully examining the introduction of smallpox vaccination – western medicine in both theory and practice – in the early 19th century. See *The Vaccinators: Smallpox, Medical Knowledge, and the "Opening" of Japan* (Stanford: Stanford University Press, 2007). However, smallpox vaccination represents more the exception than the rule, with even Jannetta acknowledging that Japan's emperor banned western medicine, except for vaccination; it did create a bridgehead that facilitated the introduction of bacteriology later in the century.

23. William W. Ford, *Bacteriology*, (New York: Paul B. Hoeber, 1939) 114.

24. John Z. Bowers, *When the Twain Meet: The Rise of Western Medicine in Japan* (Baltimore: The Johns Hopkins University Press, 1980).

25. Fluency in German was required of Japanese physicians so they could access the latest bacteriological research. "The Preparation of the Japanese Medical Officer," *Journal of the Association of Military Surgeons* 18 (1905-06): 292-293.

26. Seaman, *The Real Triumph of Japan*, 167-68. Seaman provided a translated copy of the hand-out.

27. Valery Havard, "The Sick and Wounded in the Russo-Japanese War," *Journal of the Association of Military Surgeons* 17 (1905-06): 546. Seaman, *The Real Triumph of Japan*, 151-52. David Walder, *The Short Victorious War: The Russo-Japanese Conflict 1904-1905* (London: Hutchinson & Co., 1970) 223. Walder related a humorous anecdote where, during the winter time, Japanese Soldiers would sprint, naked, from the heated bath houses to their barracks across the freezing Manchuria plains – a show of true dedication to cleanliness!

28. Shigemichi Suzuki, "Note on the Sanitary Condition of the Imperial Japanese Army During the Late Russo-Japanese War," *Journal of the Association of Military Surgeons* XIX no. 5 (November 1906): 433. Suzuki was the Surgeon General of the Japanese Navy during the Russo-Japanese War.

29. For the Japanese emphasis on preventive medicine and sanitation, see John van Rensselaer Hoff, "The Japanese as Military Sanitarians," *Journal of the Association of Military Surgeons* XIV (1903-04): 379-80.

30. Seaman, *From Tokyo to Manchuria with the Japanese*, 232-33. Seaman, "Observations in the Russo-Japanese War," 21-22. Seaman, *The Real Triumph of Japan*, 117, 146-47. Friedrich Prinzing, *Epidemics Resulting from Wars*, (London: Oxford at the Clarendon Press, 1916) 297.

31. Suzuki, "Note on the Sanitary Condition of the Imperial Japanese Army During the Late Russo-Japanese War," 434-35.

32. John van Rensselaer Hoff, "Medico-Military Notes in Manchuria," *Journal of the Association of Military Surgeons* XIX (1906): 112. "The Japanese and Russian Military Medical Matters," *Journal of the Association of Military Surgeons* XIV (1903-04): 182. Prinzing, *Epidemics Resulting From Wars*, 297.

33. Seaman, *The Real Triumph of Japan*, 154. "A Report from Vice Admiral Kataoka, Commander in Chief 3rd Squadron," in M. Kinai, *The Russo-Japanese War: Official Reports* (Tokyo: The Shimbashido, 1905) 57. During the winter, the ground froze for several meters; this layer of frozen earth prevented ground water from seeping in and contaminating wells. Havard, "The Sick and Wounded in the Russo-Japanese War," 538.

34. Dysentery proved the most deadly infectious disease for Japan, killing over 6,000 Soldiers. "Prevalence of Disease: War and Infectious Disease Before 1914,"

*Public Health Reports* 56 (21 March 1941): 549. Kean, "The Prevention of Disease in the Army and the Best Method of Accomplishing that Result," 33. Hoff, "Medico-Military Notes in Manchuria," 121-28. Prinzing, *Epidemics Resulting From Wars*, 297. Seaman, *The Real Triumph of Japan*, 106.

35. Hoff, "Medico-Military Notes in Manchuria," 97-98.

36. Michael Worboys, "Almroth Wright at Netley: Modern Medicine and the Military in Britain, 1892-1902," in *Medicine and Modern Warfare*, edited by Roger Cooter, Mark Harrison, and Steve Sturdy, 77-98 (Atlanta: Rodopi, 1999) 88-90.

37. Much discussion in the medical and especially the military medical profession focused on typhoid and particularly on causation and vectors. For the seminal work at the time, see Walter Reed, Victor Vaughan, and Edward Shakespeare, *Report on the Origin and Spread of Typhoid Fever in US Military Camps during the Spanish War of 1898* (Washington DC: Government Printing Office, 1904). See also the Enno Sander Prize winning essay by Frederick Smith, "The Differential Diagnosis of Typhoid Fever," *Journal of the Association of Military Surgeons* XIV (1903-1904): 69-94.

38. Some articles suggested an innate Japanese immunity to typhoid explained their ability to control the disease. "Some Considerations Connected with the Relative Immunity of the Japanese Armies from Typhoid Fever," *Lancet* 165 no. 4264 (20 May 1906): 1365-66.

39. E. H. Wilson, "Anti-typhoid Inoculations," *Journal of the Association of Military Surgeons* XIII (1903-04): 79-80.

40. Compulsory vaccination was rare in all countries at this this time, with the practice being the subject of much debate. See, for example, Peter Baldwin, *Contagion and the State in Europe, 1830-1930* (Cambridge: Cambridge University Press, 1999) chapter 4.

41. Suzuki, "Note on the Sanitary Condition of the Imperial Japanese Army During the Late Russo-Japanese War," 436.

42. There is a suggestion that Japan did use some cholera vaccines (see "Prevalence of Disease," 500), but no hard evidence to substantiate this claim. For a contemporary evaluation of cholera vaccination, see Edward Shakespeare, *Report on Cholera in Europe and India*, (Washington: Government Printing Office, 1890) 502-03, 548-55, 576, 625-26, 629-30, 660, and especially Chapter VI, entitled "Preventive Inoculation of Cholera."

43. Hoff, "Medico-Military Notes in Manchuria," 129. Havard, "The Sick and the Wounded in the Japanese War," 535. Seaman, *The Real Triumph of Japan*, 224-35. Suzuki, "Note on the Sanitary Condition of the Imperial Japanese Army During the Late Russo-Japanese War," 436. Seaman discusses the presence of a factory in Japan that produced the smallpox vaccination.

44. Stanhope Bayne-Jones, *The Evolution of Preventive Medicine in the United States Army, 1607-1939* (Washington DC: Office of the Surgeon General, 1968) 140.

45. Kenneth J. Carpenter, *Beriberi, White Rice, and Vitamin B: A Disease, a Cause, and a Cure* (Berkeley: University of California Press, 2000).

46. This insistence on a bacterial etiology for beriberi was not at all unique to the Japanese but rather represented a common view throughout Europe and America, too. K Codell Carter, "The Germ Theory of Disease, Beriberi, and the Deficiency Theory of Disease," *Medical History* 21 (1977): 119-136.

47. Alan Hawk, "The Great Disease Enemy, Kak'ke (Beriberi) and the Imperial Japanese Army," *Military Medicine* 171 no. 4 (April 2006): 333-339.

48. Quoted in Seaman, *From Tokyo through Manchuria with the Japanese*, 240. Seaman does not provide a source for the quote.

49. David Salsburg, *The Lady Tasting Tea: How Statistics Revolutionized Science in the Twentieth Century* (New York: Henry Holt and Company, 2001). For more on medical statistics in the 19th century, see John M. Eyler, *Victorian Social Medicine: the Ideas and Methods of William Farr* (Baltimore: the Johns Hopkins University Press, 1979), especially chapter 2. Both accounts demonstrate the over-simplicity and thus inaccuracy of the battle deaths:disease deaths ratio, and thus its inappropriateness a metric of success for comparing wars.

50. Hydraulic and mechanical recoil systems for artillery appeared in the 1870s, allowing for a higher rate of fire. Artillery caused twice as many casualties in this conflict as in the Franco-Prussian War, which medical authorities noticed and explored in their writings. For the role of artillery in the Russo-Japanese War, see especially General de Négrier, *Lessons of the Russo-Japanese War*, translated by: E. Louis Spiers (London: Hugh Rees, Ltd. 1906) 42-54. Also, L. Z. Soloview, *Actual Experiences in War: Battle Action of Infantry; Impressions of a Company Commander*, translated by the War Department (Washington DC: United States Army General staff, 1906) 6. Francis Roger Sedgewick, *The Russo-Japanese War: A Sketch: First Period – The Concentration* (London: Swan Sonnenschien & Co., 1909) 192. Walder, *The Short Victorious War*, 291. Hoff, "Medico-Military Notes in Manchuria," 131. Charles S. Butler, "Wounds Produced by Japanese Projectiles," *Journal of the Association of Military Surgeons* 18 (1905-06): 284. Hoff, "Medico-Military Notes in Manchuria," 136, 139. Seaman, *From Tokyo to Manchuria with the Japanese*, 48. Seaman, "The Real Triumph of Japan or the Conquest of the Silent Foe," 541; H. Nimier, "Wounds by Artillery Projectiles,

Hand Grenades and Land Mines in the War in Manchuria," Translated by Charles Wilcox. *Journal of the Association of Military Surgeons* XVIII (1905-06):166, 122.

51. Quoted in Sedgwick, *The Russo-Japanese War: A Sketch*, 191. See also Ian Hamilton, *A Staff Officer's Scrapbook During the Russo-Japanese War* (London: E. Arnold, 1907).

52. Jay Winter has pioneered the importance of historically contrived memory of war over factual reality. See, for example, his book *Sites of Memory, Sites of Mourning: the Great War in European Cultural History* (New York: Cambridge University Press, 1995).

53. See minutes to the meeting of the Association of Military Surgeons in *Journal of the Association of Military Surgeon*, Vol. 17, pp. 520-22 and p. 502.

54. Duncan, "Comparative Mortality of Disease and Battle Casualties," 143. Specifically, he was arguing against "the absurd conclusion[s]" of by Homer Lea." Lea's arithmetic is correct, but Lea does not factor other variables into his equations. Seaman's numbers corresponded closely with those of Lea. Interestingly, this essay won the Seaman Prize, even as it contradicted much of Seaman's earlier work. It does not cite Seaman.

55. Many modern military medical histories still accept Japanese medical victory – and priority – in the Russo-Japanese War uncritically. See, for example, Carol R. Byerly, *Fever of War: The Influenza Epidemic in the U.S. Army during World War I* (New York: New York University Press, 2005) 51. Wintermute, *Public Health and the US Military*, 162. Gillet, *The Army Medical Department, 1865-1917*, 325.

56. Connor, "Before the World in Concealed Disgrace," 50.

57. "Instruction in Hygiene at West Point," *Journal of the Association of Military Surgeons* 17 (1905-06): 148. "A Department of Military Hygiene at West Point," *Journal of the Association of Military Surgeons* 17 (1905-06): 475.

58. Wintermute, *Public Health and the U.S. Military*, 169.

59. Mary C. Gillet, *The Army Medical Department, 1917-1941* (Washington DC: Center of Military History, 2009) and Jonathan H. Jaffin, "Medical Support for the American Expeditionary Forces in France During the First World War," MA thesis, Command and General Staff College, 1991.

60. Quoted in Paul Starr, *The Social Transformation of American Medicine: The Rise of a Sovereign Profession and the Making of a Vast Industry* (New York: Basic Books, 1982), 141. Starr argues that this transformation also reflected the general rise in the respectability of the medical profession – military and civilian – over these years. See also Conner, "Before the World in Concealed Disgrace," 50.

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During the US Civil War, minimal attention was given to sanitation and other basic hygiene conditions in the field. These photos depict a battlefield staging area for wounded Soldiers pending treatment and/or evacuation  Photo courtesy of Borden Institute.

# Submission of Manuscripts to the *Army Medical Department Journal*

The *United States Army Medical Department Journal* is published quarterly to expand knowledge of domestic and international military medical issues and technological advances; promote collaborative partnerships among the Services, components, Corps, and specialties; convey clinical and health service support information; and provide a professional, high quality, peer reviewed print medium to encourage dialogue concerning health care issues and initiatives.

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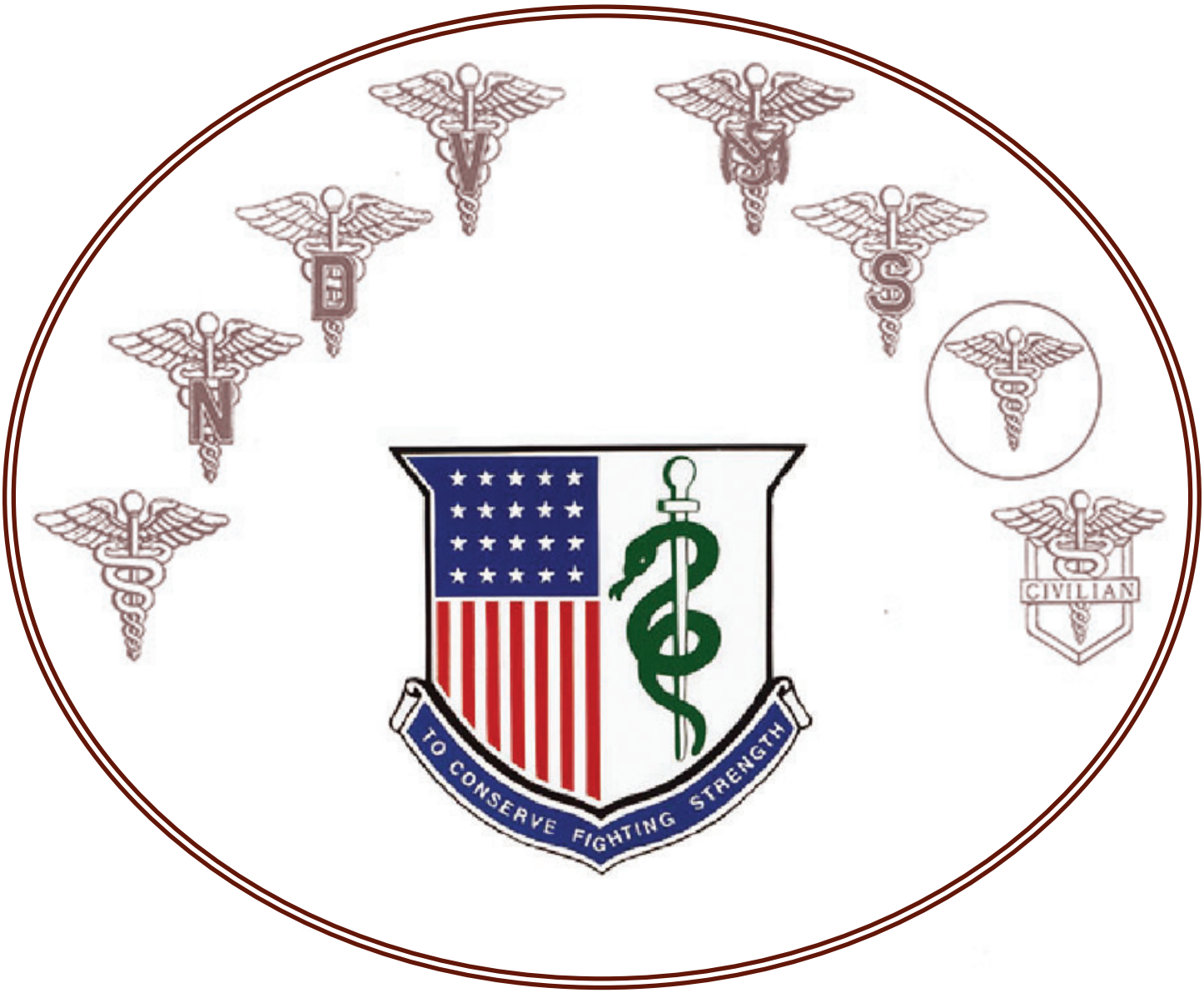


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