The migration of carbapenem-resistant Acinetobacter baumannii from the battlefields of Iraq and Afghanistan to the healthcare facilities of the Veterans Health Administration

Jeffery Rogers
University of Nebraska Medical Center

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Research Report: The migration of carbapenem-resistant *Acinetobacter baumannii* from the battlefields of Iraq and Afghanistan to the healthcare facilities of the Veterans Health Administration

Jeffery C. Rogers, MPH Candidate
University of Nebraska Medical Center, College of Public Health, Department of Epidemiology

Committee
Sharon J. Medcalf, PhD – University of Nebraska Medical Center
Abraham D. Mengist, PhD, MSc. – University of Nebraska Medical Center
Makoto M. Jones, MD, MSc. – University of Utah / Veterans Health Administration

Abstract
Multidrug-resistant organisms (MDRO) pose a great threat to health across the globe. That threat is also felt in the Veterans Health Administration (VHA). Wounded warriors returning home from the battlefields of Iraq and Afghanistan may have brought with them MDROs, such as the bacterium *Acinetobacter baumannii*, as they have transitioned from military service into the VHA facilities. This study investigates the interconnectedness of military service in the Department of Defense (DoD) and a lifetime of care at VHA through a longitudinal tracking of a linked cohort of combat veterans with battlefield injuries and subsequent MDR infections of *A. baumannii*. This study has sought to understand the spread of this MDRO beyond returned combat veterans as a potential reservoir to others throughout the nationwide VA healthcare system. This study will highlight the downstream implications of emerging MDROs brought back home from future foreign wars and campaigns that U.S. Armed Forces become engaged in. Furthermore, it will underscore the need for modernization of the current MDRO identification and surveillance capabilities of VHA to adopt more utility of available molecular techniques. With appropriate pathogen identification and surveillance, this knowledge can have a significant impact on infection prevention and control programs, antibiotic stewardship plans and drug formularies that are used both locally and nationwide.
Table of Contents

Overview of Tables and Figures ........................................................................................................... 3
Acronym Dictionary ............................................................................................................................... 4
Chapter 1 – Introduction......................................................................................................................... 5
Research Question ................................................................................................................................. 5
Specific Aims ......................................................................................................................................... 5
Significance ............................................................................................................................................ 6
Chapter 2 – Background ....................................................................................................................... 7
Description of the Health Problem ....................................................................................................... 7
Scientific Background ............................................................................................................................. 9
Limitations and gaps in existing literature .......................................................................................... 13
Chapter 3 – Data and Methods ............................................................................................................ 14
Study design .......................................................................................................................................... 14
Data Sources and Measurement .......................................................................................................... 14
Setting and study population .............................................................................................................. 15
Variables ............................................................................................................................................ 17
Analytic Plan .......................................................................................................................................... 18
Statistical Analysis ............................................................................................................................... 18
Chapter 4 – Results ............................................................................................................................... 19
Study population .................................................................................................................................. 19
Descriptive data .................................................................................................................................... 20
Outcome data .......................................................................................................................................... 23
Other Analyses Considered .................................................................................................................. 27
Chapter 5 – Discussion ......................................................................................................................... 28
Summary ............................................................................................................................................... 28
Key results ............................................................................................................................................ 28
Strengths and Limitations ...................................................................................................................... 30
Interpretation ......................................................................................................................................... 31
Conclusion ............................................................................................................................................ 35
Cited Literature ..................................................................................................................................... 37
Appendix A: VHA Health Care Utilization ......................................................................................... 40
Appendix B: Author Biography and Curriculum Vitae ...................................................................... 42
Overview of Tables and Figures

Table 1: Trauma Care Levels Within Combat Zones

Table 2: Variables of Consideration

Table 3: Detailed Pathogen Phenotype Definition

Table 4: Incidence Rates of CRAb and *Acinetobacter baumannii* (Ab) infections among DoD Personnel and VHA Patients

Table 5: Trend Analysis for Proportions of CRAb Infections among DoD Personnel and VHA Patients

Figure 1: Map of Operation Enduring Freedom and Operation Iraqi Freedom

Figure 2: Mechanism of activity among carbapenemase enzymes on carbapenem antibiotics

Figure 3: Electron Micrograph of a biofilm *Acinetobacter baumannii* on collagen substrate

Figure 4: CDC assessment of CRAb and its impact to morbidity, mortality, and economic burden

Figure 5: Study population of DoD and VHA

Figure 6: Number of military personnel in Iraq and Afghanistan from FY2002-2012

Figure 7: Total enrollments in VHA from CY2003-2010 across all eras (WWII – Post 9/11)

Figure 8: Enrollments in VHA among OEF/OIF Veterans CY2003-2012

Figure 9: Combat status of OEF/OIF Veterans by combat deployment status

Figure 10: Incident infection cases of *A. baumannii* and CRAb infections among DoD personnel from Iraq and Afghanistan battlefields CY 2008-2015

Figure 11: Incident infection cases of *A. baumannii* and CRAB infections among VA patient across all conflict eras (WWII – Post 9/11) CY2003-2012

Figure 12: Incident infection cases of *A. baumannii* and CRAB infections among OEF/OIF Era Veterans only enrolled in VA health services CY2003-2012

Figure 13: Service-connected disabled Veteran’s utilization of healthcare services and benefits increased from 59% in 2007 to 70% by 2016. Over 93% of service-connected disabled Veterans were enrolled in VHA in 2016

Figure 14: The likelihood of service-connected disabled Veterans pursuing VHA health benefits and services increases as a function of the Veteran’s disability rating from 0-100% disabling.
## Acronym Dictionary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAL</td>
<td>Bronchoalveolar lavage</td>
</tr>
<tr>
<td>CAI</td>
<td>Community-acquired Infection</td>
</tr>
<tr>
<td>CDC</td>
<td>Centers for Disease Control and Prevention</td>
</tr>
<tr>
<td>CDM</td>
<td>Common Data Model</td>
</tr>
<tr>
<td>CDW</td>
<td>Corporate Data Warehouse</td>
</tr>
<tr>
<td>CPO</td>
<td>Carbapenemase-Producing Organism</td>
</tr>
<tr>
<td>CR</td>
<td>Carbapenem-resistant</td>
</tr>
<tr>
<td>CRAb</td>
<td>Carbapenem-resistant <em>Acinetobacter baumannii</em></td>
</tr>
<tr>
<td>CS</td>
<td>Carbapenem-sensitive</td>
</tr>
<tr>
<td>DAVINCI</td>
<td>DoD and VA Infrastructure for Clinical Intelligence</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>ESBL</td>
<td>Extended-spectrum β-lactamase</td>
</tr>
<tr>
<td>FY</td>
<td>Fiscal Year</td>
</tr>
<tr>
<td>GNR</td>
<td>Gram-negative rod</td>
</tr>
<tr>
<td>HAI</td>
<td>Healthcare-acquired Infection</td>
</tr>
<tr>
<td>HIE</td>
<td>Health Information Exchange</td>
</tr>
<tr>
<td>IRB</td>
<td>Institutional Review Board</td>
</tr>
<tr>
<td>JTTTR</td>
<td>Joint Theater Trauma Registry</td>
</tr>
<tr>
<td>LRMC</td>
<td>Landstuhl Regional Medical Center, Germany</td>
</tr>
<tr>
<td>MDRO</td>
<td>Multi-Drug-Resistant Organism</td>
</tr>
<tr>
<td>MEDEVAC</td>
<td>Medical Evacuation</td>
</tr>
<tr>
<td>MRSA</td>
<td>Methicillin-resistant <em>Staphylococcus aureus</em></td>
</tr>
<tr>
<td>MTF</td>
<td>Military Treatment Facility</td>
</tr>
<tr>
<td>OEF</td>
<td>Operation Enduring Freedom</td>
</tr>
<tr>
<td>OIF</td>
<td>Operation Iraqi Freedom</td>
</tr>
<tr>
<td>OMOP</td>
<td>Observational Medical Outcomes Partnership</td>
</tr>
<tr>
<td>PFGE</td>
<td>Pulsed Field Gel Electrophoresis</td>
</tr>
<tr>
<td>qPCR</td>
<td>Quantitative Polymerase Chain Reaction</td>
</tr>
<tr>
<td>SNP</td>
<td>Single Nucleotide Polymorphism</td>
</tr>
<tr>
<td>SQL</td>
<td>Structured Query Language, by Microsoft</td>
</tr>
<tr>
<td>TIDOS</td>
<td>Trauma Infectious Disease Outcomes Study</td>
</tr>
<tr>
<td>VA</td>
<td>Department of Veterans Affairs</td>
</tr>
<tr>
<td>VHA</td>
<td>Veterans Health Administration</td>
</tr>
<tr>
<td>VINCI</td>
<td>Veterans Health Information Systems and Technology Architecture</td>
</tr>
<tr>
<td>VISTA</td>
<td>Veterans Health Information Systems and Technology Architecture</td>
</tr>
<tr>
<td>WGS</td>
<td>Whole-Genome Sequencing</td>
</tr>
<tr>
<td>XDR</td>
<td>Extensively drug-resistant</td>
</tr>
</tbody>
</table>
Chapter 1 – Introduction

Research Question
Multidrug-resistant organisms (MDRO) have long been recognized as a tremendous global threat as they show more and more resistance to commonly used antibiotics used to treat common infections [3]. Many experts have warned of what is referred to as the post-antibiotic era, in which the drugs that we have relied upon for decades will become less reliable and even completely ineffective at treating and managing bacterial infections due to drug resistance.

The Veterans Health Administration (VHA), the healthcare arm of the Department of Veterans Affairs (VA), is the largest integrated healthcare system in the United States of America serving 9 million military veterans in all 50 states and territories. VHA hospitals and clinics lie downstream from those in the Department of Defense (DoD) as military personnel transition from military service to civilian service in VA. This study examined the relationship of incidence of carbapenem-resistant *Acinetobacter baumannii* (CRAb) infections, an MDRO, from the increase in enrollments of military veterans with a combat deployment to either Iraq or Afghanistan in support of Operation Iraqi Freedom (OIF) or Operation Enduring Freedom (OEF), respectively.

Specific Aims
This study has sought to demonstrate the interconnected nature of the relationship between DoD and VHA by showing increased incidence rate in the number of CRAb infections across VHA associated with returning wounded warriors from the battlefields of Iraq and Afghanistan as a possible reservoir and their subsequent enrollment in VHA. While this DoD-VA connection of
disease exposure has been inferred in an upstream to downstream relationship, it has not ever been demonstrated across the entire VA healthcare system using VA data[4, 5].

The DoD has invested a great deal of resources into the molecular identification and surveillance of MDROs within its population across the organization. This information is available to military physicians and other professionals through electronic databases and other partnerships [4-7]. However, across its 153 medical centers and hospitals, VHA does not currently utilize advanced molecular methods of identification or surveillance for MDROs or underutilizes existing molecular techniques such as polymerase chain reaction (PCR) [8]. This makes it challenging for physicians to know exactly which pathogen they are initially faced with as they treat their patients. Modernization of laboratory pathogen identification practices using molecular techniques such as quantitative polymerase chain reaction (qPCR), pulsed field gel electrophoresis (PFGE), ribotyping and whole genome sequencing (WGS) would allow for adequate identification and molecular surveillance of MDROs to be conducted across the entire across the organization [9].

**Significance**

The findings of this study demonstrate the interconnectedness of the DoD and VA and the downstream implications for infectious diseases with such a relationship. These implications will have impacts on drug formularies used in treatment of infections, antibiotic stewardship plans, and infection control policies at both the local and national level. Furthermore, this study has underscored the importance of adopting molecular microbial identification and surveillance practices that will prevent the spread of MDROs for existing veteran patients and
improve the transition of wounded warriors to VA health care and their treatment outcomes while at VHA.

Chapter 2 – Background

Description of the Health Problem
The two major conflicts that the United States has most recently been engaged in are Operation Enduring Freedom (Greater Southwestern Asia, the Philippines, and North Africa) and Operation Iraqi Freedom (Greater Middle East) as seen in Figure 1. Many military personnel would serve multiple combat tours in one or both theaters of operation. The nature of combat in these two conflicts have been conventional as has been the case in many previous wars, but one distinctive characteristic about these two wars are the enemy’s use of improvised explosive devices (IEDs) or roadside bombs detonated remotely when U.S. forces are in proximity to the device. These explosive devices have caused a great deal of casualties across the two battlefields. Casualty rates show an increase in the comparison of wounded casualties to fatalities compared to previous U.S. conflicts in Vietnam and the Persian Gulf. Mortality rates
are relatively low considering the length of both campaigns and the technicalities of combat across these two theaters [10]. However, combat lifesaving first aid and advances in battlefield medicine and body armor have resulted in many wounded warriors returning from these battlefields with a variety of injuries resulting in increased survivability [7, 11].

Battlefield triage takes place within combat zones, especially regarding trauma cases resulting from combat injuries. These levels are defined in Table 1. Many wounded warriors requiring medical evacuation (MEDEVAC) have sustained significant bone and soft tissue damage and due to the nature of combat injuries, widespread wound contamination, which make up care levels IV and V. This made infection control along MEDEVAC pathways difficult to manage [4, 5].

Table 1. Trauma Care Levels Within Combat Zones

<table>
<thead>
<tr>
<th>Level</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Point of injury/first responder care</td>
</tr>
<tr>
<td>II</td>
<td>Resuscitation and surgical stabilization at medical units</td>
</tr>
<tr>
<td>III</td>
<td>Medical/surgical care at combat support or other theater hospitals</td>
</tr>
<tr>
<td>IV</td>
<td>Evacuation to regional medical center location (Landstuhl Regional Medical Center, Germany)</td>
</tr>
<tr>
<td>V</td>
<td>Definitive treatment/rehabilitation at major tertiary care medical centers in United States</td>
</tr>
</tbody>
</table>

34% of combat casualties that were medically evacuated from the combat zone were diagnosed with an infection during their hospital stay. 20% involved skin and soft tissue infection (SSTI) and another 6% were osteomyelitis [12]. Epidemiology studies of war infections suggest that the majority of those evacuated under Level IV and V trauma are due to Gram negative bacteria species, including A. baumannii [13, 14]. However, while A. baumannii has represented a
significant burden of the battlefield infection complications among wounded casualties, *A. baumannii* is not captured in ICD-9 codes within the JTTR and therefore underrepresented in clinical significance studies [11]. Complications from battlefield injuries, such as combat-related infections, can persist long after departure from military service and into civilian life where this study focuses [5].

Scientific Background

*Acinetobacter baumannii* is a gram-negative coccobacillus bacterial organism with a well-known reputation as an opportunistic nosocomial pathogen due to its environmental resilience by avoidance to desiccation on fomites, contaminating hospital environments, and its multidrug-resistant profile [7, 14-20]. Although not a particularly virulent wild type organism (in its natural state), when put under constant stress conditions, such as antimicrobial pressure, it can manifest its ability to be very problematic for hospitals for this is how this organism can shift in its expressed phenotype from being sensitive to antimicrobial drugs to a resistance of antimicrobial drugs [16, 21]. Not only is this organism a threat to patients, but staff alike. One such documented case demonstrated an occupational transmission of this organism from an infected patient to healthcare worker [22]. *A. baumannii* is known to possess a rather large resistome, which is the collection of genes that enable antibiotic resistance and that give this organism its competitive edge against treatment drugs [23]. This bacterium is unique in that it has acquired an ability to demonstrate resistance to carbapenem antibiotics, a class of beta-lactam antibiotics active against many Gram-positive and

![Figure 2 – Mechanism of activity among carbapenemase enzymes on carbapenem antibiotics](image)
Gram-negative organisms; these drugs are usually reserved for the most resistant infections which this study has focused on [3, 24]. *A. baumannii* also belongs to another class of concerning pathogens, namely the ESKAPE pathogens. The ESKAPE pathogens are a group of bacteria (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* Sp.) that present difficult-to-treat options for physicians due to acquired resistance genes, the increase in disease burden and increased mortality rates due to treatment complications and demand a coordinated global response for surveillance of antimicrobial resistance[21].

Carbapenem-resistant *Acinetobacter baumannii* (CRAb) include a highly problematic class of MDROs, namely the carbapenemase-producing organisms (CPO). There are many mechanisms resulting in the CRAb phenotype: namely efflux pumps, pathogenic gene islands within its genome, which promote horizontal gene transfer through the use of plasmids and include carbapenem-hydrolyzing oxacillinase-encoding genes (Oxa23-like, Oxa24-like, Oxa51-like, Oxa58-like), other beta-lactamase enzymes, the ability to make adjustments to outer membrane proteins such as penicillin binding proteins, or make adjustments to metabolic pathways (porins) and the ability to produce biofilms [16, 21, 25-28]. Plasmids are of particular concern for spreading antimicrobial resistance because contained within plasmids are integrons. *A. baumannii* contains both class I and class II integrons which have been strongly associated with antibiotic resistance and the spread of
resistance in healthcare settings from contact with other bacteria in the hospital environment such as Enterobacteriaceae or Pseudomonas species. The most notable example of integron transfer between species of bacteria is that of Pseudomonas and A. baumannii with the attainment of the class I integron which contains blaVEB-1 extended-spectrum β-lactamase (ESBL) and six other antimicrobial resistance genes, obtained from P. aeruginosa [14, 20].

One study, examining carbapenem-resistant Gram-negative organisms, discovered that among CPOs, the carbapenem resistance rate in A. baumannii was 40.1% in blood samples, 50.4% in respiratory samples, 42% in urine samples, and 42% in other types of samples [29]. Morbidity is also impacted as those patients with carbapenem-resistant (CR) infections had much longer length-of-stay in both general medical and intensive care wards. The crude odds ratio for hospitalization mortality comparing (CR) vs. carbapenem-sensitive (CS) organisms were 1.31 for Escherichia coli isolated from respiratory samples to 3.91 for A. baumannii isolated from blood samples. Overall, patients with CR infections had longer hospital stays, more antibiotic drug treatment, higher mortality rates and higher economic burden to the hospital than those with CS infections [29].

In 2019, the Centers for Disease Control and Prevention (CDC) has reclassified CRAb from a serious threat in its last report in 2013, to an urgent threat, the most perilous classification in its threat assessment matrix. CRAb has been responsible for approximately

Figure 4 – CDC assessment of CRAb and its impact to morbidity, mortality, and economic burden.
Source: Centers for Disease Control and Prevention[3]
8,500 hospitalizations, 700 deaths and healthcare costs totaling $281M in the United States alone in 2017[3].

Risk factors for MDRO infections include chronic obstructive pulmonary disease (COPD), diabetes mellitus, renal disease, excessive alcohol consumption, smoking and other immunocompromising conditions such as cancer and organ transplants [24]. This is of particular concern for the population of VHA, where its members are disproportionately older in age and exhibit more comorbidities than the general population [30]. For example, prevalence of diabetes mellitus in the VHA population is 25%, while the general population is approximately 13% [30, 31]. Furthermore, due to the occupational hazards and unique exposures of military service, such as burn pits or radiation exposure, healthcare delivery among the veteran population is very unique [32]. High prevalence of risk factors such as these in VHA makes management and treatment of bacterial infections challenging, let alone the treatment of MDROs [26].

While infection cases of A. baumannii in the United States are not uncommon, multidrug-resistant strains of A. baumannii infection cases in the United States, once rare, are on the rise [3, 15]. CRAb was not observed in the VA on a large scale until wounded warriors began integrating into VA hospitals and clinics from the OEF/OIF battlefields they were casualties on while in military service [33].

The DoD has invested a great deal of resources into molecular technologies (such as whole genome sequencing) in the identification and surveillance of CRAb and other MDROs, which have originated from Operation Enduring Freedom (Afghanistan)/Operation Iraqi Freedom
(Iraq) (OEF/OIF) battlefields [4, 5, 7, 14, 34]. DoD healthcare and research laboratories have been able to identify and track patient samples using these molecular techniques [6]. Unfortunately, the VA does not have this level of molecular granularity in its in-house laboratory practices for routine surveillance purposes and therefore the identification of clonal outbreaks of CRAb and other MDROs can be challenging [6, 8].

Furthermore, because CRAb from OEF/OIF battlefields has a much different antibiotic resistance profile from other A. baumannii strains encountered in the United States, the implications on the effectiveness of the current drug formulary used by VA physicians and pharmacies are significant [6, 35]. With advanced knowledge, using proposed laboratory pathogen identification practices as an outcome recommendation of this study, improvements to the facility level or national level Antibiotic Stewardship plan could be applied and appropriate drugs or combination of drugs to produce favorable treatment outcomes will be possible [9]. But currently, VA physicians and pharmacists do not have comprehensive information to design the appropriate treatment plan that will produce the most favorable outcomes as possible and mitigate the spread of MDROs.

Limitations and gaps in existing literature
Previous studies [4, 5] assessing the long-term impact of battlefield injuries have only considered complications from battlefield trauma but have not considered the impact of a foreign MDROs such as CRAb to an entire hospital system with a vulnerable population. This study has assessed the risk this exposure will have on not just one medical center, but across the entire organization.
Chapter 3 – Data and Methods

Study design
This study was designed as a retrospective case control study relating the migration of CRAb from DoD battlefields to VHA facilities. It was hypothesized that the prevalence of CRAb in VHA has been relatively low prior to the recent conflicts in Iraq and Afghanistan. It was further hypothesized that due to the influx of enrolled combat veterans in VHA, particularly after the troop surge of 2007, that incidence rates of CRAb cases would increase significantly across the organization. Comparing the number of CRAb cases to the number of enrolled OEF/OIF veterans that have entered VHA should show significant correlation. Counts of carbapenem resistant *Acinetobacter baumannii* (CRAb) infections among hospitalized patients was tracked each year for purposes of incidence monitoring in the VA population nationwide. Inclusion of *A. baumannii* that did not fit the operational definition for CRAb was included as well for comparison purposes as screening/identification for MDROs such as CRAb was not consistent across VHA [8]. As a result, there may be some cases of CRAb that are underrepresented in VHA.

Data Sources and Measurement
The VHA has been a pioneer in the electronic health record, with structured medical data available nationwide as early as 1999. VHA stores patient-level data in a hierarchical health information system called Veterans Health Information Systems and Technology Architecture (VistA). This information is made available to authorized data users through access to the VA Corporate Data Warehouse (CDW) and VA Informatics and Computing Infrastructure (VINCI),
which is a high-performance computing environment that provides research teams with a secure and central location for data access and application development. The CDW is used throughout the entire healthcare system and therefore can be used to survey patient records using Microsoft Structured Query Language (SQL) programming in a relational database environment. Adding to these capabilities is a data source known as DoD and VA Infrastructure for Clinical Intelligence (DAVINCI), which uses the Observational Medical Outcomes Partnership (OMOP) and Common Data Model (CDM). Using a common patient identifier and primary key across both data sources will allow for identification of those patients who sustained battlefield injuries while in active-military status and allow for further observation of this cohort as they move within the VA system.

Data collection for this project was completed under a study protocol approved by the University of Utah School of Medicine, Department of Internal Medicine Institutional Review Board (IRB) for use in the Veterans Health Administration. Data extraction for this project was performed in Microsoft SQL Server Management Studio 18 (Microsoft Redmond, WA).

**Setting and study population**
During the early stages of the OEF/OIF conflicts, the incidence of *Acinetobacter spp.* was noted among casualties and among environmental samples of MTFs across the two battlefield theaters [7]. This study examined a sample of cases from the DoD in which battlefield injuries were or were not sustained on OEF/OIF battlefields from 2008-2012* resulting subsequent infections from *A. baumannii* and CRAb. Battlefield injury status was indicated by a flag within the DAVINCI database. This group of OEF/OIF combat soldiers would be followed into VHA to
see if incidence of CRAb would increase across the organization. Another sample of controls consisted of OEF/OIF era Veterans that did not deploy to OEF/OIF battlefields.

*Note: There is a limitation of the DAVINCI data source in that battle injury and clinical microbiology laboratory data are only available from 2008 forward. As a result, analysis of data from earlier in the two conflicts (2003-2007) were not available.

Within VHA, nationwide cohort of combat veterans was retrospectively created from the period 2003 through 2010 who served in either OEF or OIF. Another retrospective cohort of patients was created along the same period, who did not have a deployment to Iraq or Afghanistan. These combat deployments were identified by a flag and record of presence or absence of combat dates within the CDW. All patients were hospitalized with microbiology cultures identifying *A. baumannii* or CRAb.

A somewhat related, but more in-depth longitudinal study conducted by Tribble et al. [21,22] examined a cohort of battlefield injuries in what is known as the Trauma Infectious Disease Outcomes Study (TIDOS). The TIDOS cohort was studied to evaluate both short and long-term infectious complications for those who sustained deployment-related injuries from Operation Enduring Freedom and Operation Iraqi Freedom combat theaters. Utilizing this same cohort is not feasible for the scope of this project, as the cohort was limited to only one VA medical center. For the purposes of this study, a nationwide cohort of enrolled Veterans Affairs patients who experienced battlefield trauma/injury was assessed.
Variables

Table 2. Variables of Consideration

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Exposure</th>
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<tbody>
<tr>
<td>DoD CRAb</td>
<td>Sustained battlefield injury</td>
</tr>
<tr>
<td>DoD Ab</td>
<td>Sustained battlefield injury</td>
</tr>
<tr>
<td>VHA CRAb</td>
<td>OEF/OIF Era Veteran</td>
</tr>
<tr>
<td>VHA Ab</td>
<td>OEF/OIF Era Veteran</td>
</tr>
<tr>
<td>OEF/OIF CRAb</td>
<td>OEF/OIF Combat Deployment</td>
</tr>
<tr>
<td>OEF/OIF Ab</td>
<td>OEF/OIF Combat Deployment</td>
</tr>
</tbody>
</table>

Operational Definitions

VHA defines a multi-drug resistant organism (MDRO) as: “microbes able to withstand the killing or inhibitory effect of several different antimicrobial agents. The exact number and types of antimicrobial classes to which a microorganism is resistant varies depending on the pathogen”[36].

Table 3. Detailed Pathogen Phenotype Definition

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Organism</th>
<th>Medications</th>
<th>Numerator</th>
<th>Denominator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbapenem-resistant</td>
<td><em>Acinetobacter</em></td>
<td>Imipenem, meropenem,</td>
<td>Any isolate with at least 1 non-susceptible result (I or R) to: imipenem, meropenem, doripenem</td>
<td>Any isolate with at least 1 susceptible (S) or non-susceptible result (I, R) to at least 1 drug in the medications category</td>
</tr>
<tr>
<td>Acinetobacter sp.</td>
<td><em>baumannii</em></td>
<td>doripenem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acinetobacter sp.</td>
<td><em>Acinetobacter</em></td>
<td>Imipenem, meropenem,</td>
<td>Any isolate with at least 1 susceptible result (I or R) to: imipenem, meropenem, doripenem</td>
<td>Any isolate with at least 1 susceptible (S) or non-susceptible result (I, R) to at least 1 drug in the medications category</td>
</tr>
<tr>
<td></td>
<td><em>baumannii</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcoaceticus complex</td>
<td>doripenem</td>
<td>R) to imipenem, meropenem, doripenem</td>
<td>susceptible result (I, R) to at least 1 drug in the medications category</td>
<td></td>
</tr>
</tbody>
</table>

**Analytic Plan**
Incidence rates of CRAb were calculated amongst the combat Veteran cohort as well as those who do not have a history of recent combat (with and without exposure).

Incidence rate ratios were calculated among DoD personnel with battlefield injuries, among VHA OEF/OIF era Veteran patients and among OEF/OIF era Veteran patients with a combat deployment to OEF or OIF battlefields to assess the risks of these exposures. Subsequent trend analyses were performed for CRAb in each group with their respective exposures.

**Statistical Analysis**
Statistical analyses among DoD and VA populations were performed by using a non-parametric, chi-square test to trend infection cases over time. Incidence rates and incidence rate ratios were calculated from summary data. Significance level at P <0.05 was set for these analyses. Analyses for this study were performed in Stata 14.2 (StataCorp, College Station, TX)
Chapter 4 – Results

Study population
The study population for this study involved both personnel from the Department of Defense and the Veterans Health Administration. In VHA, Veterans are classified by the era of conflict in which they served under; some veterans can be classified under multiple eras, such as WWII, Korea and Vietnam. Serving under a particular era does not necessarily mean that a veteran served in a combat zone; combat zone designations are indicated by the Department of Defense and Congress. To be considered as having served in a combat deployment, a military member will be temporarily assigned to serve a tour of duty in one of these locations for a designated amount of time. This is what is meant by a combat deployment to a battlefield theater.

In VHA, these conflict eras span from World War II era until the present day which is considered the Gulf War era. The Gulf War era is subdivided by those Veterans that served in the Persian Gulf War (1990-1991) as well as to the present time which includes Operation Enduring Freedom and Operation Iraqi Freedom as geographically indicated in Figure 1. As indicated in Figure 5
Figure 5. Study population of DoD and VHA

Descriptive data
The distribution of troop levels in both combat theaters over time in Figure 6 show that most of the commitment of resources were spent in support of Operation Iraqi Freedom.
Figure 6. Number of military personnel in Iraq and Afghanistan from FY2002-2012*  
*Data from Congressional Research Service, DoD – Joint Chiefs of Staff, “Boots on the Ground Reports” [2]

Total enrollments in VA services shown in Figure 6 indicate that during the years that demand for resources in the form of personnel during the OEF/OIF conflicts were ongoing, there is an apparent drop in the number of veterans enrolling in VA health services. However, after the troop surge of 2007, the number of enrollments in VA healthcare services increased substantially into 2010.
Among the most active enrollments were the OEF/OIF veterans enrolling in VA services from CY 2003-2010 as seen in Figure 7.
Among OEF/OIF era veterans considered for this study, the proportion of those with a combat deployment are lower comparatively than those without a combat deployment to an OEF or OIF battlefield.

![Graph of OEF/OIF Combat Status at Separation Date]

**Figure 8. Enrollments in VHA among OEF/OIF Veterans CY2003-2012**

**Outcome data**

Incident cases of CS *A. baumannii* and CRAB infections among DoD military personnel during the OEF/OIF conflicts indicate that both outcomes were increasing, peaked in 2010 began to fall by 2011 and fell dramatically as major combat operations diminished in 2012 when most troops were pulled out from Iraq and mission tempo in Afghanistan had been significantly scaled back. At which point, cases of both CRAb and *A. baumannii* are negligible.

Among DoD personnel who sustained a battle injury while in Operation Enduring Freedom (OEF) and/or Operation Iraqi Freedom (OIF), had 8.2 times the rate of having a CRAb infection.
compared to those without a battle injury during the study period (2008-2012) with an incidence rate of nearly 10 infections per 1,000 persons compared to those without a battle injury.

**Figure 10.** Incident infection cases of *A. baumannii* and CRAb infections among DoD personnel from Iraq and Afghanistan battlefields CY 2008-2015

Incident cases of *A. baumannii* and CRAb infections across VA involving all eras. Figure 10 shows a wide proportion margin between CS *A. baumannii* cases and CRAb cases.
Figure 11. Incident infection cases of *A. baumannii* and CRAB infections among VA patient across all conflict eras CY2003-2012

Although not as dramatic, in VHA, the observation among OEF/OIF era Veterans was that this group had 1.7 times the rate of having a CRAb infection as compared to the general VHA population during the study period (2003-2012) as compared to the general VHA population. While initially hypothesized to demonstrate a significant relationship between those in the VHA population who were OEF/OIF Veterans and had a combat deployment to either battlefield theater and develop CRAb infection or have an incident presentation upon enrollment to VHA, this group demonstrated a marginal statistical relationship.

In VHA, incident cases of *A. baumannii* and CRAB among OEF/OIF veterans follows a similar pattern to DoD group where the margin between the proportion of both outcomes is narrow as seen in Figure 12.
Table 4. Incidence Rates of CRAb and Acinetobacter baumannii (Ab) infections among DoD Personnel and VHA Patients Compared to No Exposure

<table>
<thead>
<tr>
<th>Group</th>
<th>Outcome</th>
<th>Exposure</th>
<th>Observation Period</th>
<th>Incidence Rate /1,000 persons</th>
<th>Incidence Rate Ratio</th>
<th>95% Confidence Interval</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHA</td>
<td>CRAb</td>
<td>OEF/OIF Era</td>
<td>2003-2012</td>
<td>0.0728</td>
<td>1.7</td>
<td>[1.441253, 1.885047]</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>VHA</td>
<td>Ab</td>
<td>OEF/OIF Era</td>
<td>2003-2012</td>
<td>0.1494</td>
<td>0.43</td>
<td>[0.3914165, 0.4684096]</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>OEFOIF</td>
<td>CRAb</td>
<td>Combat</td>
<td>2003-2012</td>
<td>0.049</td>
<td>0.92</td>
<td>[0.5642105, 1.426329]</td>
<td>0.7151</td>
</tr>
<tr>
<td>OEFOIF</td>
<td>Ab</td>
<td>Combat</td>
<td>2003-2012</td>
<td>0.049</td>
<td>0.30</td>
<td>[0.1857809, 0.449398]</td>
<td>&lt; .0001</td>
</tr>
</tbody>
</table>

*By 2012, most DoD personnel had been pulled from Operation Iraqi Freedom (Figures 6 and 10); analysis from 2008 through 2011 was also considered; 2012 omitted.

Results from the linear trend analyses could not be fit in a linear fashion. This formulation sets the trend as the proportion of CRAb amongst A. baumannii isolates. Due to limited counts, and other seemingly inconsistent/missing data, CRAb incidence trends were difficult to ascertain. Among OEF/OIF veterans, so few counts were observed that the statistical package could not calculate a p-value for the trend. Limitations to this study may have contributed to the gaps in available data.
Other Analyses Considered
Utilization of healthcare is important when determining risk in a hospital population. Among OEF/OIF veterans, the likelihood of this group to utilize VHA healthcare services increased as the percentage of a disability for a service-connected injury increased as indicated in Figure 13 within Appendix A. In other words, those with the most injuries are seeking VHA services. This is represented in. Service-connected disabled Veteran’s utilization of healthcare services and benefits increased from 59% in 2007 to 70% by 2016. Over 93% of service-connected disabled Veterans were enrolled in VHA in 2016 as indicated in Figure 14 within Appendix A.
Chapter 5 – Discussion

Summary
While there were many MDROs to consider amongst returning OEF/OIF veterans, *A. baumannii* was selected for this study because of its ability to specifically impact healthcare settings and the speed to which it develops resistance [15, 24, 29, 37]. *A. baumannii* has impacted combat veterans in a variety of injuries sustained during the OEF/OIF conflicts as lifesaving techniques and advances in medical evacuation availability have made survival on these battlefields much more likely [7, 11]. It was hypothesized that this group of returning combat veterans might be reservoirs for *A. baumannii* and CRAb infections that could be migrated into hospitals and medical centers within the Veterans Health Administration and increase infection incidence as a result.

Key results
We were pleased to see that our findings confirmed higher incidence of CRAb among military personnel with battle injuries than those without battle injuries. Among DoD personnel who sustained a battle injury while in Operation Enduring Freedom (OEF) and/or Operation Iraqi Freedom (OIF), had 8.1 times the rate of having a CRAb infection compared to those without a battle injury during the study period (2008-2012). In VHA, the observation among OEF/OIF era Veterans was that this group had 1.7 times the rate of having a CRAb infection as compared to the general VHA population during the study period (2003-2012). Among OEF/OIF era veterans in VHA, incidence rates of CRAb among those with and without a previous combat deployment, there was no statistically significant relationship. We remained puzzled as to the low incidence of CRAb in VHA and explored these findings further.
Care of the evacuated casualties has also been improved from previous conflicts to the point where many soft tissue wounds sustained during combat were no longer infected or even colonized once arriving at a Level V tertiary medical center (National Naval Medical Center) in the U.S. upon departure from Level IV care at LRMC and others. Although not a definitive study, it represents a snapshot of the complexity of wound management from combat areas [38]. This may have contributed to the lack of a statistical support between incidence of CRAb among OEF/OIF era veterans in VHA that had a combat deployment (exposed) to the OEF/OIF theaters and those that did not (not exposed).

Other explanations of low incidence of A. baumannii and CRAb cases in VHA could be that by March 2007, the VHA was able to launch a successful comprehensive initiative aimed at preventing methicillin-resistant Staphylococcus aureus (MRSA) across the network of 153 medical centers and hospitals [39]. This was a very robust initiative in that it involved admission screenings for MRSA colonization via nasal swab and required contact precautions (gown and gloves) for any contact with the patient and their surroundings as well as extensive handwashing [40]. This program was able to reduce Staphylococcus aureus infections by 43% and MRSA infections by 55% [39]. While strategically aimed at the prevention of MRSA among VHA patients, the successful impact this program had on the reduction of incident cases of MRSA may have carried over into reducing incidence rates of other MDROs such as CRAb. Another study examining hospital-onset Gram-negative rod (GNR) bacteremia in VHA also noticed that the success of the MRSA prevention program had a horizontal effect on their initial research target surrounding the impact of GNRs (E. coli, Klebsiella spp., Pseudomonas aeruginosa) in bacteremia within VHA [41]. They also discovered because of the MRSA Prevention initiative
that there was a sustained reduction in hospital-acquired GNR bacteremia incidence rates by - 42% from January 2003 until December 2013. Similar observations of lower than normal counts were made among GNR subgroup analyses of each bacterial species and susceptibility profiles [41] Another recently published study within VHA examining extensively drug-resistant (XDR) *Acinetobacter baumannii*, observed a similar effect among this virulent phenotype [42]. It is not uncommon for successful infection prevention programs to have these types of effects. In the civilian non-VHA population, healthcare associated infections among CRAb had decreased from 58% in 2011 [43] to only 39% from 2015 – 2017 [44].

However, this study was able to identify higher incidence rates of CRAb among OEF/OIF era veterans as compared to the general VA population as seen in Figures 11 and 12, respectively. While this study found that incidence rate ratio of CRAb in VHA at 1.7 among those OEF/OIF era veterans compared to the general population at VHA, the study was not able to make a significant connection among OEF/OIF era with a combat deployment and those without.

**Strengths and Limitations**

This study underscores the interconnected relationship between the Department of Defense (the feeding organization) and the Department of Veterans Affairs (the receiving organization) and why a strong partnership should exist between these two departments of the US Government. The OEF/OIF conflicts, although the most recent, are not the last that the United States Armed Forces will be involved in as conditions and threats around the world are in constant flux. Future conflicts and wars may unearth other emerging pathogens that could threaten our ability to manage them effectively. Those risks then have the potential to be vertically transferred from the DoD population to the VHA population. Thus, knowing exactly what they are and what they are capable of will equip professionals with the tools they will need to be sentries to protect our
nation’s wounded warriors and prevent unnecessary collateral damage among a vulnerable population at VHA.

Limitations of this study included the incompleteness of data within the DAVINCI data source. DAVINCI only captured data from 2008 forward, so earlier analysis of the OEF/OIF conflicts within the DoD group was not possible. Although not a strong signal in VHA, a closer look at the OEF/OIF conflicts in their earlier stages would indicate the potential of A. baumannii without a diluted effect by the time these individuals reach VHA facilities. Furthermore, the DAVINCI data source captured mostly VA-enrolled patients and we were therefore unable to assess those that did not enroll in VA services. As a result, we were unable to perform an appropriate comparative analysis between DoD and VA populations during the early years of the OEF/OIF conflicts (2003-2007). Future studies on this topic should consider using the Joint Theater Trauma Registry (JTTR), which is the definitive source for battlefield injuries sustained during combat operations for the United States Armed Forces.

Further limitations are the inconsistent laboratory practices for identification of MDROS within VHA. These inconsistencies among the carbapenem-producing organisms (CPOs) produce ambiguity in the surveillance results and subsequent infection control procedures. Although the VHA is a national organization with directives aimed nationwide, many local practices are what prevail [8].

**Interpretation**

This study underscores the need for cooperation in many areas between the DoD and VA due to the upstream-downstream relationship of these two departments. The first area where cooperation is needed is records management. At the present time, records for military members are maintained within DoD and not well-shared with VA. In April 2020, the joint Health
Information Exchange (HIE) launched, which is a major step forward in the exchange of medical data, but still a significant distance from ideal. This can make medical histories challenging for VA physicians and other professionals to get an accurate representation of the challenges a particular patient may be experiencing if left to incomplete medical records or patient reporting only. However, there is a push to streamline one single record that will follow a military recruit from basic training to separation from military service and into VHA as part of the Federal Electronic Health Record Modernization Program, which the findings of this report support.

The second major area of cooperation is the research and development efforts the DoD has engaged on with regard to the diagnostics and epidemiology that have been done on the lab results of those afflicted with pathogenic microorganisms while in military service, particularly the molecular infrastructure that can definitively identify highly problematic pathogens, such as the ESKAPE cluster of pathogens that have such a major impacts on healthcare [7, 21, 34].

Many medical centers throughout the VHA rely upon only culture-based lab data for identification, diagnosis and later treatment of infections impacting veteran patients [8]. While culture data cannot be replaced entirely, rapid nucleic acid identification is the direction clinical labs by and large have adopted in providing accurate diagnostics in healthcare settings.

Pneumonia for example is one of the leading causes of death in the world. Lower respiratory infections are the 4th greatest cause of mortality in the world; responsible for 2.6 million deaths globally in 2019 [45]. In the United States alone in 2017, 1.3 million instances occurred where pneumonia was listed as the primary diagnosis [46]. Furthermore, this disease has an economic impact of ~$10 billion in the United States [47]. Pneumonia is a communicable disease affecting all age groups and is characterized by infections of viral and/or bacterial and/or fungal
This makes the identification of a pneumonia-causing pathogen or even multiple pathogens, challenging for providers and further complicates treatment planning for favorable clinical outcomes. While in-vitro culture and Gram staining have been standard practice of microbial identification in clinical microbiology since the days of Pasteur in the late 19th century, these methods have their limitations. Cultures, for example, take time 24-48 hours for most aerobic organisms and even longer for those anaerobic or more fastidious in nature [48].

Multiplex real-time quantitative polymerase chain reaction (qPCR) is a molecular diagnostic assay that can detect organisms in real-time using nucleic acids which culture may not be able to successfully recover. A major advantage of the syndromic testing of the pneumonia panel is the ability to detect polymicrobial infections in which viral-viral infections may be detected or bacteria-bacteria, or even if viral-bacterial infections are occurring [49]. One such qPCR manufacturer, BioFire® FilmArray® Pneumonia (PN) Panel, will produce a rapid molecular analysis report in about 1 hour across 33 different targets from sputum, endotracheal aspirate and bronchoalveolar lavage (BAL) clinical samples. These targets involve 8 common respiratory viruses, 15 common pneumonia-causing bacteria, 3 atypical bacteria. An added value of the PN panel is its ability to also detect select antimicrobial resistance genes: Methicillin resistance (x3), carbapenemases (x6) and extended spectrum beta-lactamases [49]. This rapid information can provide the treating physician with real-time information about the pathogen/s afflicting their patients so they can make the most informed decision about an appropriate treatment plan to produce the best possible clinical outcome and protect the integrity of the antibiotic stewardship plan at a local or national level by not propagating antibiotic resistance by improper broad-spectrum empiric therapies [50].
Another molecular technique that will provide the best and most complete information about a microbial pathogen for VA epidemiologists, clinical laboratory scientists, pharmacists and treating physicians is a technology called whole-genome sequencing (WGS) [9]. WGS is a molecular technique that maps out an organism’s entire genome in a single run and is the future of medicine at the personal level. What this allows medical scientists to do is see the full potential of the organism at a molecular level and understand the lineage of that organism through phylogenetic mapping by comparing the regions of the genome by means of a collection of single nucleotide polymorphisms (SNPs). In one study, *A. baumannii* isolates at the clonal level were able to be identified at a threshold of 2,500 core SNPs, while CRAb outbreak strains were identified at a threshold of 2.5 core SNPs [9]. WGS has a great deal of application towards ESKAPE pathogens and other MDROs in detecting strain types and investigations into outbreaks [9, 21, 50]. *A. baumannii* strain recognition, has medically important consequences as each clonal lineage has different impacts to healthcare settings and their populations [9, 18, 23].

Many of the lab techniques in practice today in VHA only identify some phenotypical expression in resistance to any given antimicrobial and only provide a limited picture of what MDROs are capable of genotypically. This gap among identification of MDROs exists in the civilian population but has also been underscored in VHA [8, 42]. Thus, there is a great missed opportunity at VHA to understand the pathogenic potential and the epidemiological patterns these organisms follow and may suggest that CRAb and other MDROs are underreported and could be another reason for such low CRAb incidence in VHA [9, 42]. We suggest the VHA either develop an in-house central reference laboratory or regional laboratories for high-throughput WGS or utilize a third-party reference laboratory to acquire such information. This
will help to better identify outbreak strains that are problematic for those in ICUs. Costs for WGS have consistently been a major barrier for integration in clinical laboratories for many organizations, however WGS is projected to get cheaper and cheaper as time goes on and therefore, VHA should be strategically planning and implementing policies and directives for the future of hospital epidemiology, infection prevention, infection control and antibiotic stewardship [9, 42].

Conclusion
Further studies using molecular data are required across large hospital systems or networks to determine if related strains are circulated and transmitted patient-to-patient or patient-to-staff member within the network to determine if the results of this study are generalizable. Awareness of the epidemiological impact of newly VA-enrollees from DoD as reservoirs should compel VHA leadership to modernize the electronic medical record, modernize current pathogen identification and surveillance systems, reconsider local and national drug formularies based off what organisms are present or threatening the population, and adjust antibiotic stewardship plans accordingly. While this study did not assess treatment outcomes for CRAb, it echoes the literature in calling for the development of new antimicrobials against MDROs [1, 51] in order to prevent the troubling prophecies of a post-antibiotic era in which the drugs we as a society have relied upon for years will be less and less effective and there are no other treatment options remaining.

MDROs such as A. baumannii, are making decisions for their survival at the molecular level as to how they adapt to thrive in their environments, whether that is in nature as a wildtype organism or as an opportunistic nosocomial pathogen in a healthcare facility. Our understanding of MDROs, research and development of new drugs/treatments, epidemiologic surveillance,
infection prevention practices and currently available treatments of MDRO infections also need to be at the molecular level if we as a medical community want to make a significant impact to the health and wellness of the populations we serve.
Cited Literature


34. VA, 2017 *Management Of Infectious Diseases And Infection Prevention And Control Programs*, N.I.D. Service, Editor. 2017, Veterans Health Administration, Department of Veterans Affairs: Washington DC.


Appendix A: VHA Health Care Utilization

Figure 13 - Service-connected disabled Veteran’s utilization of healthcare services and benefits increased from 59% in 2007 to 70% by 2016. Over 93% of service-connected disabled Veterans were enrolled in VHA in 2016

Source: U.S. Veterans Eligibility Trends and Statistics, 2016 [52]
Figure 14 - The likelihood of Veterans with a service-connected disability pursuing VHA health benefits and services increase as the Veteran’s disability rating increases from 0-100% disabling.

Source: U.S. Veterans Eligibility Trends and Statistics, 2016 [52]
Appendix B: Author Biography and Curriculum Vitae

Biography

Jeffery C. Rogers is a graduate student and MPH candidate with the University of Nebraska Medical Center with the College of Public Health within the Department of Epidemiology. Currently he functions as a Research Health Science Specialist in the Health Services Research and Development Department at the Veterans Health Administration. This role involves supporting principal investigators from around the country with a variety of research needs involving clinical research and public health research projects involving both chronic and infectious disease, to include COVID-19, as well as mental health in the nation’s largest integrated healthcare system, the Veterans Health Administration.

It has been a privilege for him to have had the opportunity to serve on active-duty military service with the United States Air Force. Some notable experiences included: supporting the airspace national security efforts during the 2002 Salt Lake Winter Olympics, coordination of events for an international treaty, an overseas combat tour to Afghanistan in support of Operation Enduring Freedom and a bachelor’s degree from the University of Alaska Fairbanks. This time spent in active-duty military service taught him the fundamental core values of integrity, service, and excellence that have followed him throughout his career.

His curiosity of microorganisms and disease began during an administrative fellowship, following the completion of a Master of Health Administration from Capella University. He was able to partner with the VA Medical Center in Salt Lake City, UT to address the prevention of Legionnaire’s disease among the facility’s patient population and visitors. He designed a program, which is still in use today, involving data collection of environmental water sampling efforts then using appropriate data management practices to provide the committee with data analysis to drive decisions regarding the mitigation of exposure to *Legionella pneumophila* bacteria, the disease agent for Legionnaire’s disease. This project was competed at the national level and received the top award for its successful planning, implementation, and organizational impact. The success of the project generated a divergence in his administrative career track to one geared more towards more science. He would later enroll at Weber State University in Ogden, UT and pursue a second bachelor’s degree in microbiology. Upon completion of this program, he functioned as a Research Microbiologist with the University of Utah studying bacterial biofilms and the roles, they play in healthcare impacts and disease burden. To date, two research publications have resulted from his work in the Bone and Joint Research Lab under Dr. Dustin L. Williams, PhD, which published in 2020.