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The Epidemiology of Clostridioides Difficile in Nebraska - A Descriptive Study Between 2018-2020

Storm Keffer
University of Nebraska Medical Center

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STORM KEFFER - EPIDEMIOLOGY

COMMITTEE CHAIR – DR. ABRAHAM MENGIST, PHD
COMMITTEE MEMBER – DR. ISHRAT KAMAL-AHMED, M.SC., PHD
COMMITTEE MEMBER – DR SHARON MEDCALF, PHD

Abstract

Objectives: *Clostridioides difficile* (*C. diff*) is a common but challenging infection both financially and medically. Due to these difficulties, *Clostridioides difficile* infection (CDI) caused by *C. diff* is a mandatory reportable disease in Nebraska and as such has been a priority disease targeted by various disease control practices across many hospitals. All CDI laboratory results are reported electronically through the Nebraska Electronic Disease Surveillance System (NEDSS). However, capturing and conceptualizing the true burden of CDIs in Nebraska has not been adequately accomplished since monitoring of CDIs began. The objective of this study is to examine the trends of *C. diff* infections and related deaths in Nebraska from 2018-2020. In addition, this study seeks to create a system to track CDIs in Nebraska through Geographic Information System (GIS) mapping for better conceptualizing of CDI burden in the state.
Methods: To examine the burden of *C. diff* on Nebraska, descriptive epidemiology using lab results reported in NEDSS from 2018-2020 and deaths reported with CDI association during the same timespan were performed using the SAS analysis tool. Social vulnerability index (SVI) provided by the Center for Disease Control and Prevention (CDC) was used to compare varying counties and CDI counts. An interactive map using GIS was created to document and visualize CDI prevalence of 2020 cases across the state of Nebraska.
Results: 8,334 CDI cases were recorded during the three-year span with case counts decreasing 36.5% from 2018-2020. The three-year prevalence rate for Nebraska was 459.07 per 100,000. Yearly incidence rates decreased yearly from 181.56 to 130.42 per 100,000 over the three-year span. 127 CDI-associated deaths were identified between 2018-2020 with increasing and decreasing numbers and rates yearly. Demographic information including gender, age, specimen/test type, race, ethnicity, and infection type of all 8,334 cases were recorded and reported. In addition to demographics, over 600 medical facilities and nursing homes were identified and stored into the state's system for future identification of CDI case locating. ANOVA and logistic regression analysis indicated that residents of high-risk SVI counties were less likely to have a CDI than both moderate and low-risk SVI county residents. Lastly, an interactive GIS map was created depicting 2020 case demographics and rates as well as case numbers and rates by local health department (LHD) jurisdiction.
Conclusion: The overall burden of CDIs has been decreasing in Nebraska since 2018, however death counts and rates have remained similar. While complications associated with CDIs due to possible comorbidities may be harder to predict and prevent, this study has shown the positive effect of antimicrobial stewardship on CDI prevalence statewide. Case demographics that have been recorded as well as SVI analysis by this study have created a baseline understanding of at-risk populations in Nebraska and when combined with the GIS map can be used to locate CDI outbreaks and decrease response time. Furthermore, the creation of the CDI GIS map has created an efficient means of disease tracking and monitoring, and specifically for all common and reportable healthcare-associated infections (HAIs) in Nebraska as it can be used as a foundational template. Overall, this study was able to successfully describe the epidemiological situation of *Clostridioides difficile* in Nebraska.

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ABBREVIATION	DEFINITION
CDI	*Clostridioides difficile* infection
LTCF	Long-term care facility
SVI	Social vulnerability index
NEDSS	Nebraska Electronic Disease Surveillance System
NEDRS	Nebraska Electronic Death Registration System
CDC	Centers for Disease Control and Prevention
EIP	Emerging Infections Program
ELR	Electronic reporting system
GIS	Geographical Information Systems
PROC SQL	SAS procedure designed to specifically locate a CDI test
PCR	Polymerase chain reaction
NAAT	Nucleic acid amplification test
EIA	Enzyme immunoassay
MMWR	Morbidity and Mortality Weekly Report
SAS	Analytical software used to perform descriptive and statistical analysis
HIPAA	Health Insurance Portability and Accountability Act
NDHHS	Nebraska Department of Health and Human Services
CFR	Case-fatality rate
LHD	Local health department
HAI	Healthcare-acquired infection
ASAP	Antimicrobial Stewardship Assessment and Promotion
ICAP	Infection Control and Prevention
OCIO	Office of the Chief Information Officer

Background

Clostridioides difficile in Healthcare

Clostridioides difficile (*C. diff*) is a toxin-producing bacterium often associated with colitis and severe diarrhea and is known to frequently reoccur after a first *C. diff* infection (CDI). CDIs are most seen in nursing home residents and are a leading health care associated infection in the United States.[1] Studies have shown that CDIs make up 10-30% of healthcare infections with asymptomatic colonization of *C. diff* seen in 2-3% in healthy individuals and 10-25% of hospitalized patients.[9-12] Hospitals are unique, complex environments that continually change with the flow of people that reside and work within them. One important aspect of *C. diff* is its ability to live on surfaces for up to five months suggesting that the hospital environment is an important risk multiplier and place of transmission for *C. diff*.[3] Consideration that inpatients are not always static and may be granted liberalized movement permissions in specific instances, it is not inconceivable that a patient can acquire a *C. diff* infection during their stay.[4,29] For those already infected with *C. diff*, viral shedding of spores can cause contamination of surfaces, devices, and of healthcare workers' bodies and attire creating reservoirs for *C. diff* usually transmitted via the fecal-oral route.[7,8] As such, a quarter of hospitalized patients will contract a hospital-acquired infection indicating that controlling pathogens such as *C. diff* should be a top priority.[5,6]

Clostridioides difficile in Long-Term Facilities

Another area of considerable CDI prevalence are long-term care facilities (LTCFs). These types of facilities include assisted living facilities, skilled nursing facilities, nursing homes, and rehabilitation centers. Common occurrences of CDIs can be correlated to extended antibiotic usage, existing comorbidities, and age. Many residents of LTCFs are elderly and as such, antibiotic usage is higher amongst LTCF populations than the general population. This in conjunction with older age and comorbidities make LTCFs a common reservoir of *C. diff*. Due to these risk factors, incidence rates of CDIs have been reported to upwards of 50% of residents in observed LTCFs.[16-20] Also keeping into consideration that residents are living in these facilities, spread of *C. diff* through interactions among residents via group gatherings and events, and the lunch hall further increases the risk of transmission and CDIs. In addition, elderly persons are more likely prone to complications if infected with *C. diff.* This unique dynamic creates a distinctive priority to control the spread of *C. diff* in LTCFs.

***Clostridioides difficile* in the General Population**

CDIs have demonstrated financial and clinical burdens on a national and state level. One study found the average length of stay for CDI inpatient treatment has been determined to be around 11 days and consequently, making CDIs an expensive infection with average CDI-attributable costs around $42,316 per infection.[2] Another study aimed specifically at determining the burden of CDIs in Massachusetts found rates of CDIs to be 132.5 per 100,000 people in 2016 and a CDI mortality rate of 6.4 per 100,000 in 2014.[13] Of the positive cases in the study, 55.6% of positives were female, and incidence rates increased with age.[13] These studies signify an extreme burden on states around the country and warrants further investigation by the states individually to understand their own *C. diff* burden. Yet the Massachusetts study is the only published *C. diff* epidemiological study performed on a statewide level.[13] Even then, this study is not indicative of the Nebraska population and has incidence and mortality rate calculations in separate years and over a one-year span. To understand Nebraska's own unique *C. diff* situation, a descriptive study must be undertaken that includes a multi-year timespan that is also broken down yearly.

Vulnerabilities and *Clostridioides difficile*

To study the effects of vulnerabilities on disease burden and catastrophic events, the CDC has created a social vulnerability index (SVI) for counties in each state with the last update being in 2016. This index is based on 15 social factors grouped into four categories and is used to indicate vulnerability to a hazardous event on a 0 to 1 scale. The first category is socioeconomic status that includes factors such as persons who are below the poverty line, unemployed, have low income, or no high school diploma. The second category is household composition and disability made up of factors such as persons 65 and older or 17 and younger, persons with disabilities, and single-parent households. The third category is minority status and language made up of two factors: persons who are part of a minority or speak English "less than well". The final category is housing and transportation made up of factors like multi-unit structures, mobile homes, crowding, persons with no vehicle, and group quarters. A higher score indicates a higher vulnerability.

Infection Control Programs for *Clostridioides difficile*

Various infection control programs have been put into place to control HAIs including CDI. The most prominent practice attributable to high rates of CDI is inappropriate prescribing and use of antimicrobials specifically, dosage, treatment duration, decision to withhold or initiate antimicrobials, and regimens.[22-27] This has led to microbial stewardship programs aimed at improving antimicrobial practices to contain the spread of pathogens such as *C. diff*. However, a systematic review has found that interventions placed on prescribing of antimicrobials had little impact on both adherence to guidelines and decreasing the number of antimicrobials being described in LTCFs.[21] Hospitals have adapted to increasing *C. diff* challenges through more microbial stewardship programs that have shown success in decreasing

CDIs. Practices such as education of staff, reinforcing of proper handwashing and isolation protocols, and monthly assessment and reviews of the practices have shown to markedly decrease CDIs in the hospital setting.[28] Such practices have been implemented statewide in Nebraska. While stewardship program implementors understand that there is a *C. diff* issue in Nebraska, they do not have a complete visual understanding of the true burden that CDIs have on the state. Nor do they have adequate conceptualization of the current *C. diff* situation in Nebraska. This lack of information does not provide appropriate feedback to these programs regarding their efficacy in lowering the prevalence of CDIs. This project aims to give these programs the tangible evidence to evaluate and adjust their protocols.

Use of Surveillance Data for *Clostridioides difficile*

The increased sophistication and advancement of the health care field has allowed for better tracking and surveillance of diseases. Nebraska has a statewide reporting system known as the Nebraska Electronic Disease Surveillance System (NEDSS) that allows for labs to be electronically reported and accessible for health systems purposes. This system provides the data to conduct studies that would otherwise be extremely limited to perform. Through NEDSS, each lab performed is reported from every hospital in the state to allow tracking and reporting of each mandatory disease. For *C. diff* specifically, NEDSS has been recording labs performed since 2018 making NEDSS a primary source to analyze CDI data as well as identifying clusters and outbreaks for immediate containment. As well as surveillance to report disease incidences, death certificate data has become a more sophisticated means to help track deaths associated with specific diseases. The Nebraska Electronic Death Registration System (NEDRS) is one such database where these deaths and their causes are reported. Using NEDSS in tandem with NEDRS we can describe the burden of CDIs in Nebraska.

Every state health department has an electronic reporting system for surveillance purposes just like the state of Nebraska. Through this surveillance data some state health departments have also done their own tracking and monitoring of CDIs whether by their own design or through the Center for Disease Control's (CDC) Emerging Infections Program (EIP). Through the EIP, the CDC has launched a *C. diff* surveillance program involving 10 state health departments and several metropolitan areas residing within the same state. While this is good for estimation of national population-based incidence and disease burden, this is not an efficient means to describe Nebraska's unique CDI burden. Furthermore, the states involved in the EIP create yearly state CDI reports only based on the metropolitan areas involved within the program. While this can paint an abstract picture of CDI burden, it does not adequately portray the true burden in the entire state. This project aims to take CDI surveillance to the next level with the use of Nebraska's electronic reporting system (ELR) and the addition of mapping. By analyzing the lab data and mapping the incidences of CDIs we will be able to better understand disease control program efficacy, the burden of CDIs on the state, *C. diff* hotspots that require more attention for targeted control measures, and potentially point towards CDI burden associated with antimicrobial use/misuse within identified hotspots in Nebraska.

Using Mapping for *Clostridioides difficile*

One way to conceptualize the spatial clustering and transmission of disease has come with Geographic Information System (GIS) techniques. While spatial analysis has been widely used since the 1960s it has developed into a prominent epidemiological tool as seen during the 2019 novel coronavirus pandemic.[14,15] With the advancement of GIS mapping, technologies such as this can provide higher insights and conceptualizations of disease burden in epidemiological practices. GIS can be used to pinpoint clustered outbreaks, identify areas that are underserved, and predict growth and transmission of disease.[14] The state of Nebraska has created GIS mapping for the 2019 novel coronavirus pandemic statewide, but it has not used this type of epidemiological practice to track other diseases and has only used GIS mapping for listing the locations of the state's biggest hospitals so the rural population can find the nearest to their area of residence. GIS has many applicable uses including creating an easy-to-read story map that allows the community and healthcare community to understand significant health burdens that are affecting both their state and local area. COVID was the first major disease that highlighted the applicability of GIS in epidemiology, but it is not the only major disease in the world. *C. diff* is a significant problem and GIS should be used to create spatial mapping for tracking purposes of CDI incidence in Nebraska.

Project Aim

This project seeks to create a baseline understanding of the current ongoing *C. diff* situation in Nebraska. Using the state's surveillance data, this study will be able to calculate incidence rates, mortality rates, as well as identify the geographic areas most affected with CDIs for targeted interventions. The study will also create an epidemiological description of CDI cases by assessing exposure statuses within the affected CDI population. This will help gain better insight into more at risk individuals in the state. Secondly, this project aims to determine the efficacy of current stewardship programs. CDI laboratory results have been collected in Nebraska's surveillance data since 2018, so a longitudinal study of trends on CDIs can be achieved. Moreover, this project aims to create a mapping system that can continuously be updated to monitor CDI cases. The state health department contains the software to use GIS mapping. By using this software, a map of the state with corresponding locations where CDI incidences have occurred will create a quick and easier concept to visualize the current *C. diff* situation in Nebraska.

Methods

Study Design and Study Setting

This project is a retrospective, population-level, descriptive epidemiological and spatial mapping study. Between the years 2018-2020, there have been over 8,000 CDI lab tests performed. To perform this study, all CDI results during this timeframe were extracted from NEDSS, placed into one excel file, and broken down into three separate excel files by year in which the CDI occurred. The master Excel file was analyzed by the SAS analysis tool coded to perform each descriptive task. Cleaning the data consisted of removing duplicate and incomplete data.

Study Population

To study mortality, incidence, and prevalence of CDIs in Nebraska, cases who have a positive laboratory test or had *C. diff* listed on their death certificate were the study population with the 2010 census tract as the denominator to calculate these rates. For incidence and prevalence calculations, all positive CDIs were included. For descriptive epidemiology purposes in this project, cases with a positive CDI lab were the study population. Another aspect that needed to be taken into consideration is that reoccurring episodes of CDI do occur. Per CDC guidelines, positive labs between 2-8 weeks in the same case are considered recurrent episodes and positive labs within two weeks are considered duplicate episodes. Our data cleaning incorporated these rules implemented by the CDC. Any consecutive positive lab that was within two weeks of the first positive lab was considered a duplicate and not a CDI. However, recurrent positive labs two weeks or more after a first positive lab were considered an independent CDI.

Data Sources

We used two sources of data: NEDSS and NEDRS. NEDSS is a real-time, integrated electronic lab recording system used by the entire state's healthcare system. NEDSS contains every laboratory test, positive or negative, for each reportable disease in Nebraska. Each event is recorded into the system for archiving and eventual analysis. NEDRS is similar to NEDSS but with death certificate data. NEDRS reports contain the main cause of death in addition to a secondary, and tertiary cause of death. *C. diff* listed in any order of cause of death was considered for mortality data.

Data Extraction, Data Cleaning, and Variables

The ELR systems for Nebraska contain raw data of every lab that is performed in Nebraska. This requires specific SAS coding to be able to extract *C. diff* specific data. Using the PROC SQL command in SAS we were able to specifically target every CDI lab that was performed between 2018 and 2020 and extract all those labs out of the NEDSS data system. However, the data extracted was still raw and required significant data cleaning to perform any analysis and descriptive epidemiology.

The ELR system comes directly from the hospitals that report the information. The interaction between facilities that order the lab test and facilities that perform the lab test are dynamic. Many facilities do not have the means to perform CDI labs and need other facilities to perform the test for them. This creates a confusion on where the CDI has been identified as some reporting facilities do not explicitly list which facility requested the CDI lab. This in addition to different styles in reporting such as only reporting the ordering facility's address create a need to perform detective-like work by backtracking where the CDI occurred. To do this, all ordering facilities and reporting facilities were organized, and the data cleaning process consisted of going through each ordering facility's address, identifying which facility that address belongs to, and unifying all ordering facilities in the SAS coding.

In addition, LTCFs are not included in the ELR systems. CDI has a higher prevalence in the LTCF areas so creating a LTCF variable to document this was pertinent. Typically, the LTCF is listed in the ordering facility so by using the same process as above we were able to pick out LTCFs that ordered a CDI lab to create the new variable. In addition, residents usually have the LTCF address listed as their own, using this data we were also able to identify several LTCFs where a CDI occurred. Another variable that required cleaning was the test type and specimen type. There are a substantial number of different names for a CDI test in the ELR system but whether they were positive or negative was consistent. Test types were organized and then categorized into four different categories: polymerase chain reaction (PCR)/nucleic acid amplification test (NAAT), enzyme immunoassay (toxin) (EIA), culture, and antigen. Specimen types were organized into unique but matching categories depending on the specimen type. The other variables that were cleaned were county where the CDI occurred and the local health department that has jurisdiction over which county. Once the county where the CDI occurred was identified the health department that provides services to that county was then able to be identified.

Variables such as specimen type, test performed, age, gender, race, infection type, ethnicity, and Morbidity and Mortality Weekly Report (MMWR) week were recorded from positive CDI labs for simple descriptive analysis. MMWR week is a 52-week timeframe corresponding to the 52 weeks in a calendar year developed by the CDC. Rather than reporting cases by the day, grouping cases within the same week allows for efficient grouping and easier identifying of potential clustering of cases. Infection type categorized whether the CDI was classified as a community associated infection, meaning the CDI was acquired outside a medical facility or clinic, or a healthcare associated infection meaning that the CDI was acquired in a medical facility. Gender, age, race, ethnicity, infection type, and MMWR week did not require much to any cleaning.

Study Analysis and Descriptive Study

CDI incidence and mortality rates for each year were calculated using the ELR surveillance data. Since this study does have a timeframe of three years, a three-year prevalence and crude mortality rate were calculated in addition to the yearly rates. Yearly incidence rates were calculated by dividing the number of positive CDI cases by the state of Nebraska's population according to the 2010 census and multiplied by 100,000 as incidence rates are reported per 100,000 people usually. The three-year prevalence was calculated by the total positive CDIs over the three years and divided by Nebraska's population. Mortality rates were calculated similarly to the incidence and prevalence rates but instead by taking the number of CDI associated deaths and dividing by the state population and reporting per 100,000. The yearly rates were then compared to the national rates as well as between each year to show trend direction.

Since *C. diff* has a more profound affect on the older population, an age-adjusted mortality rate was calculated among three different age categories: 0-5, 6-64, and 65+. People between the ages 0 and 5 make up 6.7% of Nebraska's population, 6 to 64 make up 77.2%, and 65+ make up 16.1% of Nebraska's population according to census bureau data. These percentages were used to calculate the denominator in our age-adjusted mortality rates for each year and the three-year study span. Additionally, case-fatality rates were also calculated yearly and over the three-year span by dividing the number of CDI deaths by the number of positive cases and recorded as a percentage. Key simple descriptive information that was analyzed through SAS included basic counts, means, and percentage make-up of gender, race, ethnicity, age, sample type, test performed, infection type, and MMWR week.

To study vulnerabilities and CDI incidence, Nebraska counties were given a SVI score based on the CDC SVI scale and placed into categories of three different vulnerabilities: low ($\leq$ 0.33), moderate (0.34-0.67), and high ($\geq$ 0.68). Once gathered and grouped accordingly, the overall number of CDI labs, both positive and negative, of the three SVI categories were then compared using ANOVA testing and logistic regression in SAS.

Cases, deaths, mortality, incidence, and prevalence rates where then broken down further by local health department (LHD). Each case number for each health department is the culmination of all the cases recorded from each county that the local health department has jurisdiction over. All rates were calculated the same as the state rates except the population of each health departments jurisdiction was used as the denominator instead of the state population. All local health department populations were found by calculating the sum of each county they cover according to census information.

GIS Mapping

2020 CDI data was used as the baseline data for the GIS map. A geographical map of Nebraska separated by LHD borders served as the template with which interactive information was entered. From there, case numbers were added up by each county within the same LHD and displayed within each local health department's unique window when clicked on. Each health department jurisdiction was shaded based on case numbers. In addition, each health department's unique incidence and mortality rates were placed along with case counts within their jurisdiction's window that could be viewed when the user clicks on the jurisdiction of their choice. Sections displaying the descriptive epidemiology of positive CDIs were placed next to the GIS map as well as the overall 2020 CDI situation to give viewers more insight. Lastly, the national rates were placed within the overall section for reference to Nebraska's CDI situation when compared nationally. All descriptive epidemiology variables placed in the GIS map were graphed based on overall numbers and percentages using bar and pie graphs, respectively.

Reporting Guidelines of the GIS Map

The GIS map and all results included were reported according to CDC, Health Insurance Portability and Accountability Act (HIPAA), and Nebraska Department of Health and Human Services (NDHHS) reporting guidelines and regulations. This included reporting CDIs by LHD jurisdiction rather than county, displaying case numbers with a certain minimum required, displaying reliable results that were gathered accurately with minimal missing data, and using the insignia and colors associated with NDHHS.

Results

The overall number of positive CDIs identified in the three-year span was 8,334 (95.63%) of 8,715 total CDI tests being administered. CDI counts were 3,296 in 2018, 2,944 in 2019, and 2,094 in 2020. 4,844 (58.12%) of all cases were female and 3,480 (41.76%) were male (table 1). 10 (0.12%) case were unknown for gender. Caucasian race made up 56.10% (4,675) of cases, 39.56% (3,297) were unknown, 3.06% (255) African American, 0.55% (46) other, 0.41% (34) American Indian, 0.30% (25) Asian, and 0.02% (2) Native Hawaiian. Non-Hispanic ethnicity made up 56.82% (4,735) of CDIs, 41.10% (3,425) unknown, and 2.09% (174) were of Hispanic ethnicity (table 1). PCR/NAAT tests made up 65.14% (5,429) of CDI tests, enzyme immunoassay toxin tests made up 32.45% (2,704) of tests. Antigen tests accounted for 2.15% (179) of tests and culture tests made up 0.24% (20) of tests (table 1). Of positive CDIs, stool samples were 98.72% (8,227), unknown samples 0.95% (79), body structure and microbial isolate samples 0.10% (8), urine samples 0.08% (7), blood samples 0.04% (3), and peritoneal fluid and abscess samples were 0.01% (1) of all collected specimens (table 1). Of all positive CDIs, 75.89% (6,325) were considered community-acquired infections, 14.91% (1,243) were considered hospital-acquired infections, and 9.19% (766) were unknown (table 1).

CDIs were also broken down by age groups (table 1). The median age of all CDIs was 65 years old (Range: 0-104 years) with the most common age (mode) being 71 years old (table 5). Of 8,334 CDIs, cases aged between 65-74 accounted for most cases at 21.53% (1,794). Cases aged between 75-84 were 17.06% (1,422), 16.02% (1,335) were between 55-64, people 85+ accounted for 11.77% (981), 45-54 were 8.84% (737), 0-19 were 8.72% (727), 20-34 were 7.74% (645), and 35-44 were 7.49% (624). Unknown ages accounted for 0.83% (69) of all positive CDIs. Age-adjusted case-fatality rates were calculated for three different age groups as well (table 6). The CFR for age group 65+ was 36.95 per 100,000, 1.36 per 100,000 for ages 6-64, and 0.00 for ages 0-5.

The overall number of CDI-associated deaths were 127. 2018 recorded the highest number of CDI associated deaths with 53 followed by 2020 with 45 and 2019 with 29 deaths. The overall prevalence between 2018 and 2020 was calculated at 459.07 per 100,000 people. Incidence rates for 2018, 2019, and 2020 were 205.28, 183.36, and 130.42 with mortality rates of 3.30, 1.81, and 2.80 per 100,000, respectively. Overall mortality rate was calculated at 7.11 per 100,000 with an overall case-fatality rate (CFR) of 1.55%. The CFR was calculated at 1.61% in 2018, 0.99% in 2019, and 2.15% in 2020.

CDIs were then broken down by LHD jurisdiction (tables 2-5). Median case count for CDIs in LHDs was 84 (Range: 6 – 820) in 2018, 87 (14 – 675) in 2019, and 72 (7 –

491) in 2020. Median incidence rates were 178.52 per 100,000 (28.56 – 308.36) in 2018, 168.67 per 100,000 (14.28 – 427.37) in 2019, and 112.52 per 100,000 (33.32 – 321.88) in 2020. Median mortality rates were calculated at 2.71 per 100,000 (0.00 – 8.65) in 2018, 0.68 per 100,000 (0.00 – 7.25) in 2019, and 2.21 per 100,000 (0.00 – 9.90) in 2020. Median CFR were 1.52% (0.00% - 10.53%) in 2018, 0.42% (0.00% - 7.14%) in 2019, and 1.58% (0.00% - 14.29%) in 2020.

CDI statistics by LHD describe Nebraska's CDI situation regionally. The number of LHDs with incidence rates over 100 has decreased yearly since 2018. However, six LHDs have seen increased incidence rates since 2018 with the highest increase occurring at Public Health Solutions health department with a 31.7% increase. Central District health department saw the highest decrease in rate at 76.9% and five total LHDs saw their rates decrease by half since 2018. Three LHDs saw a rise in incidence rates from 2018-2019 that were followed by a decrease in rates in 2020. Three LHDs saw the opposite with decreasing rates from 2018-2019 followed by an increase in 2020. Over the course of entire study, Panhandle health department jurisdiction observed the highest prevalence at 699.07 while Dakota health department had the lowest prevalence at 76.17.

The ANOVA analysis calculated a p-value less than 0.001 indicating a difference among one or more of the SVI groups (table 7). From there, the logistic regression model indicated that persons in high risk SVI counties were less likely to have a CDI case than persons in low risk SVI counties ($p<.0001$), persons in high SVI counties were also less likely to have a CDI than persons in moderate risk SVI counties ($p<.0001$), and persons in low risk SVI counties were less likely to have a CDI than persons in moderate risk SVI counties ($p=0.0437$). Specifically, the odds that persons in moderate risk SVI counties have a CDI is 8.3 [5.4,12.8] times higher than high risk SVI county residents. The odds that persons in low risk SVI counties have a CDI are 5.4 [4.3,6.7] times higher than moderate risk SVI county residents. The odds that persons in moderate risk SVI counties have a CDI are 1.5 [1.0,2.4] times higher than low risk SVI county residents (table 8).

The GIS map was created using 2020 CDI data and with an ultra-link. The link was placed inside the healthcare-associated infection (HAI) Data and Reports section inside the NDHHS HAI website displayed as "Clostridioides Difficile Cases in Nebraska 2020". Upon clicking the link, users are brought to a map of Nebraska shaded different colors. The map of Nebraska is outlined by local health department jurisdictions with county borders inside the jurisdictional borders (figure 1). LHD jurisdictions are shaded according to the total CDI counts within their borders; light yellow implies lower case counts and darker blue implies higher case counts. Each LHD section can be clicked on to view their specific case number, incidence rate, mortality rate, and case-fatality rate (figure 2). It is important to note that the numbers are LHD numbers and not county numbers. In the top left corner of the map, several tabs were created to display certain aspects of the 2020 CDI data. The overall tab depicts the total positive CDI labs, the total negative CDI labs, total people tested, total deaths, state and national incidence and mortality rates, and the age-adjusted mortality rate for Nebraska (figure 3). In order, the other demographic data displayed within separate tabs were positive CDIs in 2020 by age, gender, test type, specimen type, infection type and CDIs by MMWR week (figures 4-9). Each demographic was shown as a percentage with a pie graph and overall number with a bar graph.

Discussion

Overall case counts decreased yearly between 2018 and 2020; 36.5% overall from 2018 to 2020. The Nebraska medicine and NDHHS antimicrobial stewardship assessment and promotion (ASAP) coalition started in 2017 as a pilot and in 2018 engaged many facilities across the state in coaching them to develop their own stewardship programs. Since 2018 antimicrobial stewardship statewide summits have been held yearly and the focus shifted to reducing CDIs in Nebraska in 2019. The focus has been on messaging and education on promoting appropriate antibiotic use in various health care settings. The overall decline in CDI incidence is indicative of the positive effect infection control and prevention (ICAP) programs have had. The national CDI incidence rate per the CDC is 130.1 per 100,000. Although, the CDI incidence rates were above the national average, the incidence rate in 2020 was equal to the national average further highlighting the positive effects of ICAP programs. The varying increase and decrease in mortality rates are more difficult to explain and are as unique as the persons who developed complications to CDIs. However, when looking at the age-adjusted mortality rates it does not come as a surprise that the senior population develops complications to CDIs more so than the younger populations. Nevertheless, Nebraska's CDI mortality rate of 2.8 was also lower than the national average of 3.9 even though it rose from the preceding year.

The age demographics and the MMWR numbers indicate that there is no seasonal preference, but that CDI appears more prominent in the elderly population. This is not surprising to see but more so only confirms studies and reports indicating higher CDI prevalence in the older population. Furthermore, CDIs typically occur due to prescription overuse. Do to that fact and that older populations are commonly on daily medications it is not surprising to see the numbers higher in the older populations. Likewise, females tend to have longer lifespans than males. This indicates that the elderly population would have a more female prominence and makes sense when considering that the female gender made up 58.12% of the positive CDI cases. For future studies, it may be worthwhile to further breakdown the age groups to find possible risk factors and exposures for their CDI outcomes. Lastly, Nebraska is predominately

Caucasian, so it does not come as a surprise to see more than half of positive CDIs affecting this specific population the most as well as those of non-Hispanic ethnicity. However, the unknown percentage is relatively high and highlights a sizable void in lab reporting. In the future, even if these high unknown issues are due to patients not reporting, it is important to reach out to reporting facilities to discuss the importance of clear and concise reporting to understand CDIs within certain racial and ethnic populations.

C. diff typically affects the colon. Since a CDI typically constitutes as an infection of the colon it would be assumed a sample from the colon area would be the typical sample to detect *C. diff*. Therefore, a stool sample would be the logical choice to run a CDI lab test on. Our results indicate that to truly be the case with almost all positive tests using a stool sample. Our results have also surprisingly shown that other structures, although uncommon, can also be used for *C. diff* detection. This creates a possible case study situation for all positive CDI labs that did not use a stool specimen to understand symptoms exhibited by the patient and the potential reasonings the provider opted for a sample other than a stool sample.

In the world of modern medicine, it is preferable to be able to diagnose and treat the patient as fast as possible before complications develop. While culture tests for *C. diff* detection are the gold standard, they are usually labor intensive, require very careful quality control, often associated with false-positive results, and results usually take the longest to achieve. These reasons are usually why providers would opt for an EIA toxin, PCR/NAAT, or antigen test. However, while antigen tests are the most rapid test, they are not confirmatory tests and usually need to be combined with either a toxin or PCR/NAAT test. The results confirm that providers would prefer PCR/NAAT or toxin test over an antigen or culture test due to their cons. Both PCR/NAAT and toxin tests are rapid results, however, toxin tests are typically a cheaper testing approach as opposed to PCR/NAAT testing but they are not as specific. Therefore, deciding on which test to perform between toxin and PCR/NAAT would appear to come down to provider preference. With PCR/NAAT tests accounting for 65.14% of total positive CDI tests, it becomes clearer that providers would prefer to have a test with high specificity and sensitivity performed at a higher cost.

Hospital acquired CDIs account for around 24 percent of all CDI infections.[7] Our results may indicate that to be the case for Nebraska as well, but they also indicate that hospital acquired CDIs may be less than 24 percent of all CDI case in Nebraska. Considering that *C. diff* is commonly viewed as a hospital acquired pathogen, it is preferable that future reporting requires strict adherence to report how the CDI was acquired.

Grouping counties by SVI and comparing their cumulative case numbers was performed as an attempt to begin understanding potential exposures that could be correlated with getting a CDI. The ANOVA test revealed that at least one of the SVI groups has a significantly higher or lower CDI caseload. However, it does not reveal which one of these groups is significantly different. The logistic regression analysis was performed to determine which group or if all the groups were different than each other, and it provided interesting results. High SVI counties accounted for 72.7% of all positive CDI cases during the three-year span, yet the odds of getting a CDI were lower than both moderate and low risk SVI counties. Considering that all the big metropolitan areas are in high SVI counties and therefore high SVI counties have a considerably higher population and thus lower incidence rates of CDIs could explain why the odds of getting a CDI are lower. However, that does not provide adequate explanation. Upon examination of the model fit statistics, the AIC, SC, and -2 Log L were all above 3,000 suggesting that the model is not a very good fit at determining CDI outcomes. This suggestion also indicates the possibility that certain social determinants and barriers within the index may not be adequate variables to help predict the possibility of a CDI outcome. Furthermore, SVI is an overgeneralization of a county and not truly indicative of the people who reside within its borders. To be able to understand CDI risks and exposures it is suggested to use other determinants or geocoding factors such as zip codes or even proximity to a medical hospital to discover any that may exist.

Creation of the GIS map required clean, accurate data with relatively low unknown percentages. Without complete material organized properly, GIS mapping of CDIs would not be considered. Furthermore, organizing the material that would be included within the map needed to include both valuable knowledge that could provide insight into the CDI situation in Nebraska and not give out any information that could lead to identification of any person who had either acquired a CDI or died from a CDI. The technology needed to create a GIS map is through the office of the chief information officer (OCIO) at the state department. Thorough communication is needed to establish and create the guidelines and parameters necessary to convey the message the map is trying to send to anyone who views it.

At the state and federal level, only COVID has been deemed an exception to all the GIS reporting guidelines. Using LHD borders and displaying rates and counts by LHD is one such guideline implemented by the state. This guideline was made with regards to HIPPA. Counties are small enough in population in Nebraska and CDIs can occur at a small enough rate that can make an individual identifiable. For instance, if a county had just one single CDI during the entire year it would make identifying that individual easier. Reporting by LHD alleviates that potential issue because all cases and rates are reported as a summation of all the counties that lie in their jurisdictions. But this does not completely get rid of the issue. Some LHDs like Douglas, Lincoln/Lancaster, and Dakota LHD govern only one county and even some of the more rural LHD jurisdictions are capable of reporting low CDI numbers. Even though the populations within Douglas and Lincoln/Lancaster LHD are large enough to make identification of those who obtain a CDI more difficult, a minimum required number of five is required to report the specific number of cases and deaths. Anything less than five requires censorship per state guidelines.

Reporting numbers as a rate makes identification more difficult and also standardizes the burden of CDIs when trying to compare LHDs or geographical locations to another. Reporting incidence and mortality rates as well as overall counts by LHD in addition to scaling their case numbers by color paints a good story to help users visualize what the burden of CDIs are in each specific area. Also, as stated above, creation of the GIS map requires clean, accurate data, with a low percentage of unknowns. The two categories of data that did not meet this requirement were the ethnicity and race categories. Until these variables can reach a lower unknown percentage, they will remain off the GIS map. In addition, even though over 600 facilities have been identified they must be left off the GIS dashboard as well as of now. Like low case numbers by county, some facilities report low numbers as well. Also, even though the SAS coding has three years' worth of reporting to be able to categorize and extract the ordering facility, the coding still needs more refining and confirmation of accuracy by further developing the code over the next several years. This will help to ensure accuracy and increase confidence to share facility specific data. With all this in mind however, there are plans to develop an internal dashboard to be used by the state only. This dashboard can contain any amount of information desired including facility, race, and ethnicity. This provides the means of auditing the map for ways to improve what the external map already created can become.

Putting a map into production does not happen until the map has shown the ability to function as a test website first. Once the map was created and shown to function correctly as a test website, creating a link, and placing it within the NDHHS website to access the map needed coordination with the state web team. The website team makes sure that the map is created according to the state's reporting guidelines in addition to the correct state colors and ensuring the state department's logo was displayed correctly. Deciding where the link was placed was up to the healthcare-associated infections epidemiology team. Once all these parameters were met, the map went into full production and was then able to be viewed by anyone who found it on the NDHHS website.

The map is designed to tell several different stories. The first story is the overall burden of CDIs on the state of Nebraska and how it compares nationally. There are very few states that do external reporting on their CDI burdens and even then, the other state departments that do report are the ones involved in the CDC's EIP program and only report the numbers of their metropolitan city involved. For future purposes, it is the hope that there will be more accessible reports like Nebraska's that can be incorporated into the map to compare where Nebraska stands on the CDI scale. The next stories are about who have been affected by CDIs and how CDIs have been determined. These stories are intended to enhance and promote further understanding of CDIs.

The final stories, and most important stories, are the unique CDI situations of each LHD embedded within the map of the state. Any persons interested in *C. diff* can click on the map and discover that the Panhandle Health Department jurisdiction has the highest CDI rate in Nebraska and Dakota Health Department has the lowest rate. They could also see that Loup Basin Health Department has the highest mortality rate and a few LHDs do not have any recorded deaths. LHD information was integral in the map creation as this allows the LHDs, and medical personnel that reside within them, the ability to determine their specific CDI situation. This in return could drive change by allowing LHDs to do their own investigating and decrease their specific rates. Eventual integration of facilities will further boost efforts in decreasing the CDI burden.

Conclusion

Clostridioides difficile is a mandatory reportable disease in the state of Nebraska, however epidemiological knowledge regarding CDI burden has been limited. This has left facilities and infection control and prevention teams with little understanding about current conditions and suppressed any progress that has been spent towards alleviating CDI conditions. This also obstructed in any attempts by antibiotic stewardship programs to identify where, why, and how interventions can be applied to any facility, clinic, or physician to eliminate needless prescription ordering. To better understand and create a sense of direction in targeting areas affected by *C. diff*, descriptive epidemiology and epidemiological mapping were necessary to understand the *C. diff* situation in Nebraska.

This project created a baseline understanding on the current and previous conditions of *Clostridioides difficile* in Nebraska. As a result of this study, we can identify over 600 medical facilities and nursing homes across the state as well as cases by LHD that can continually be used to update the *C. diff* situation into a GIS story map. Through GIS mapping conceptualizing the areas hit most by *C. diff* are more readily available to ICAP teams thus decreasing the time to outbreak response. The GIS mapping is also a means for each LHD to view the current *C. diff* areas in their areas as well as the burden *C. diff* has on their areas. In addition, calculations in trends of incidence have visually demonstrated the successful attempts at mitigating the CDI issue in the state showing a continued decrease in over the last three years. While there have been studies on the epidemiology of *C. diff* on a statewide scale, those studies did not take it further to include GIS mapping to visualize current *C. diff* burden in the state. While this is a good reactive approach to disease studying, our study takes it further to provide a more proactive approach in disease monitoring and prevention as the map can be updated regularly. This approach is key to improvement of public health effectiveness in the communities it serves.

There are a few limitations to the study. The first limitation regards data quality, collection, and reporting. Facility reporting is not explicit and requires detailed coding to dig up the true facility where the CDI occurred. Having reporting that is clear and concise allows for better data quality and thus more accurate data. While the SAS coding was specifically tailored to 2018, 2019, and 2020 data to ensure accuracy for these years specifically, the coding will need to continually be monitored for following years to ensure data quality is accurate. Furthermore, this study highlighted the limitations in understanding race and ethnicities effect on CDIs. This is another example ushering the need for better reporting quality into the ELR system. There are limitations regarding SVI and its potential correlation with CDIs. SVI is a generalization of each county and not specifically indicative of different communities within the area. Finding and using a more specific means such as zip code could provide for a better method to study CDIs on the population. In addition, this would create a better fitting model to understand and better determine vulnerabilities and their correlation with CDIs.

In addition, the possible effect and interaction between COVID and *C. diff* is a potential limitation to this study. While it is known that both affect older aged people and have diarrhea as a symptom, it is not known if COVID testing has led to decreases, or even increases, in *C. diff* testing and detection. CDI numbers are lower in 2020, but correlation between COVID and *C. diff* is a further topic for discussion. However, moving forward from 2020, the GIS map created during this study will continue to serve as a point of reference for facilities and ICAP teams in the struggle with *C. diff.*

The overall focus on CDIs and hospital-acquired infections has increased dramatically within the last several years. With the map produced in this study, the CDI containment movement can now move with more precise actions targeted in specific areas hit by *C. diff* to mitigate both its spread and burden on the state of Nebraska. In addition, this study has opened the door for GIS mapping's ability to support the public health movement of more innovative disease tracking of hospital-acquired infections leading to more comprehensive ways public health can survey disease burden across the entire state.

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Appendix A

Gender	Cases	Percent
Female	4844	58.12%
Male	3480	41.76%
Unknown	10	0.12%
Age Group	**Cases**	**Percent**
65-74	1794	21.53%
75-84	1422	17.06%
55-64	1335	16.02%
85+	981	11.77%
45-54	737	8.84%
0-19	727	8.72%
20-34	645	7.74%
35-44	624	7.49%
Unknown	69	0.83%
MAX	104	
MIN	0	
MEDIAN	65	
MODE	71	
Race	**Cases**	**Percent**
White	4675	56.10%
Unknown	3297	39.56%
Black or African American	255	3.06%
Other Race	46	0.55%
American Indian or Alaska Native	34	0.41%
Asian	25	0.30%
Native Hawaiian or Other Pacific Islander	2	0.02%
Ethnicity	**Cases**	**Percent**
Not Hispanic or Latino	4735	56.82%
Unknown	3425	41.10%
Hispanic or Latino	174	2.09%
Test Type	**Cases**	**Percent**
PCR/NAAT	5429	65.14%
Enzyme Immunoassay (Toxin)	2704	32.45%
Antigen	179	2.15%
Culture	20	0.24%
Unknown	2	0.02%
Specimen Source	**Cases**	**Percent**
Stool	8227	98.72%
Unknown	79	0.95%
Body Structure	8	0.10%
Microbial Isolate	8	0.10%
Urine	7	0.08%
Blood	3	0.04%
Peritoneal Fluid	1	0.01%
Abscess	1	0.01%
Infection Type	**Cases**	**Percent**
Community-Acquired	6325	75.89%
Hospital-Acquired	1243	14.91%
Unknown	766	9.19%

Table 1. CDI demographics by gender, age group, race, ethnicity, test type, specimen source, and infection type 2018-2020.

Appendix B

LHD	Cases	Cases 2018	Cases 2019	Cases 2020
Central District	342	147	161	34
Dakota	16	6	< 10	7
Douglas	1986	820	675	491
East Central	153	54	47	52
Elkhorn Logan Valley	261	80	85	96
Four Corners	242	109	78	55
Lincoln/Lancaster	1397	562	480	355
Loup Basin	81	38	26	17
North Central	222	67	87	68
Northeast	44	19	14	11
Panhandle	618	175	245	198
Public Health Solutions	327	82	137	108
Sarpy/Cass	713	331	218	164
South Heartland	315	107	151	57
Southeast	211	86	85	40
Southwest	131	65	43	23
Three Rivers	462	195	142	125
Two Rivers	390	168	135	87
West Central	214	71	67	76
Unknown	209	114	65	30
Overall	8334	3296	2941	2094
MAX	1986	820	675	491
MIN	16	6	14	7
MEDIAN	261	86	111	68

Table 2. CDIs by year with LHDs.

LHD	CDI Prevalence (per 100,000)	CDI Rate 2018	CDI Rate 2019	CDI Rate 2020
Panhandle LHD	699.07	197.86	277.14	223.97
North Central LHD	478.51	144.42	187.52	146.57
Northeast LHD	140.19	60.53	44.60	35.05
Dakota LHD	76.17	28.56	14.28	33.32
Elkhorn Logan Valley LHD	457.88	140.35	149.12	168.42
Three Rivers LHD	594.56	250.95	182.74	160.86
Douglas LHD	384.06	158.57	130.53	94.95
East Central LHD	294.28	103.86	90.40	100.02
Sarpy/Cass LHD	387.33	179.81	118.43	89.09
Southeast LHD	536.34	218.60	216.06	101.68
Lincoln/Lancaster LHD	489.48	196.91	168.18	124.38
Four Corners LHD	547.31	246.52	176.41	124.39
Central District	452.52	194.51	213.03	44.99
South Heartland LHD	681.55	231.51	326.71	123.33
Two Rivers LHD	411.41	177.22	142.41	91.78
Loup Basin LHD	400.97	188.11	128.71	84.15
West Central LHD	542.69	180.05	169.91	192.73
Southwest LHD	327.85	162.67	107.62	57.56
Public Health Solutions LHD	592.65	148.62	248.30	195.74
Overall	459.07	181.56	162.17	115.35
MAX	699.07	250.95	326.71	223.97
MIN	76.17	28.56	14.28	33.32
MEDIAN	457.88	179.81	168.18	101.68

Table 3. CDI prevalence and incidence rates by year with LHDs.

LHD	Mortality Rate (per 100,000)	Mortality Rate 2018	Mortality Rate 2019	Mortality Rate 2020
Panhandle LHD	5.66	1.13	1.13	3.39
North Central LHD	2.16	0.00	0.00	2.16
Northeast LHD	9.56	6.37	3.19	0.00
Dakota LHD	4.76	0.00	0.00	4.76
Elkhorn Logan Valley LHD	3.51	0.00	1.75	1.75
Three Rivers LHD	15.44	6.43	3.86	5.15
Douglas LHD	6.77	2.32	1.35	3.09
East Central LHD	1.92	1.92	0.00	0.00
Sarpy/Cass LHD	8.69	2.72	2.17	3.80
Southeast LHD	5.08	2.54	0.00	2.54
Lincoln/Lancaster LHD	4.91	2.80	1.40	0.70
Four Corners LHD	6.78	4.52	0.00	2.26
Central District	5.29	3.97	0.00	1.32
South Heartland LHD	8.65	8.65	0.00	0.00
Two Rivers LHD	10.55	3.16	3.16	4.22
Loup Basin LHD	19.80	4.95	4.95	9.90
West Central LHD	5.07	2.54	0.00	2.54
Southwest LHD	2.50	2.50	0.00	0.00
Public Health Solutions LHD	12.69	5.44	7.25	0.00
Overall	7.00	2.92	1.60	2.48
MAX	19.80	8.65	7.25	9.90
MIN	1.92	0.00	0.00	0.00
MEDIAN	5.66	2.72	1.13	2.26

Table 4. CDI mortality rates by year with LHDs.

LHD	Case-Fatality Rate	Case-Fatality Rate 2018	Case-Fatality Rate 2019	Case-Fatality Rate 2020
Panhandle LHD	0.81%	0.57%	0.41%	1.52%
North Central LHD	0.45%	0.00%	0.00%	1.47%
Northeast LHD	6.82%	10.53%	7.14%	0.00%
Dakota LHD	6.25%	0.00%	0.00%	14.29%
Elkhorn Logan Valley LHD	0.77%	0.00%	1.18%	1.04%
Three Rivers LHD	2.60%	2.56%	2.11%	3.20%
Douglas LHD	1.76%	1.46%	1.04%	3.26%
East Central LHD	0.65%	1.85%	0.00%	0.00%
Sarpy/Cass LHD	2.24%	1.51%	1.83%	4.27%
Southeast LHD	0.95%	1.16%	0.00%	2.50%
Lincoln/Lancaster LHD	1.00%	1.42%	0.83%	0.56%
Four Corners LHD	1.24%	1.83%	0.00%	1.82%
Central District	1.17%	2.04%	0.00%	2.94%
South Heartland LHD	1.27%	3.74%	0.00%	0.00%
Two Rivers LHD	2.56%	1.79%	2.22%	4.60%
Loup Basin LHD	4.94%	2.63%	3.85%	11.76%
West Central LHD	0.93%	1.41%	0.00%	1.32%
Southwest LHD	0.76%	1.54%	0.00%	0.00%
Public Health Solutions LHD	2.14%	3.66%	2.92%	0.00%
Overall	1.52%	1.61%	0.99%	2.15%
MAX	6.82%	10.53%	7.14%	14.29%
MIN	0.45%	0.00%	0.00%	0.00%
MEDIAN	1.24%	1.54%	0.41%	1.52%

Table 5. CDI CFR rates by year with LHDs.

Appendix C

Age-Adjusted CFR (per 100,000)	Rate	Population %
0-5	0.00	6.70%
6-64	1.36	77.20%
65+	36.95	16.10%

Table 6. Age-adjusted CFR. Population percentage based on 2010 census data.

ANOVA Analysis						
		SS	DF	MS	F	Sig
SVI Group	Between Groups	13.43	2	6.71	165.61	<.0001
	Within Groups	344.10	8488	0.04		
	Total	357.53	8490			

Table 7. ANOVA analysis on SVI groups per case number.

Regression Analysis						
Variable	B	SE	P-Value	OR	95% CL for OR	
Model 1						
SVI Group (ref: High SVI)						
Low SVI	1.69	0.11	<.0001	5.40	4.33	6.73
Moderate SVI	2.12	0.22	<.0001	8.34	5.43	12.80
Model 2						
SVI Group (ref: Low SVI)						
Moderate SVI	0.43	0.22	0.0437	1.54	1.01	2.36

Table 8. Logistic regression analysis on SVI groups per case number.

Appendix D

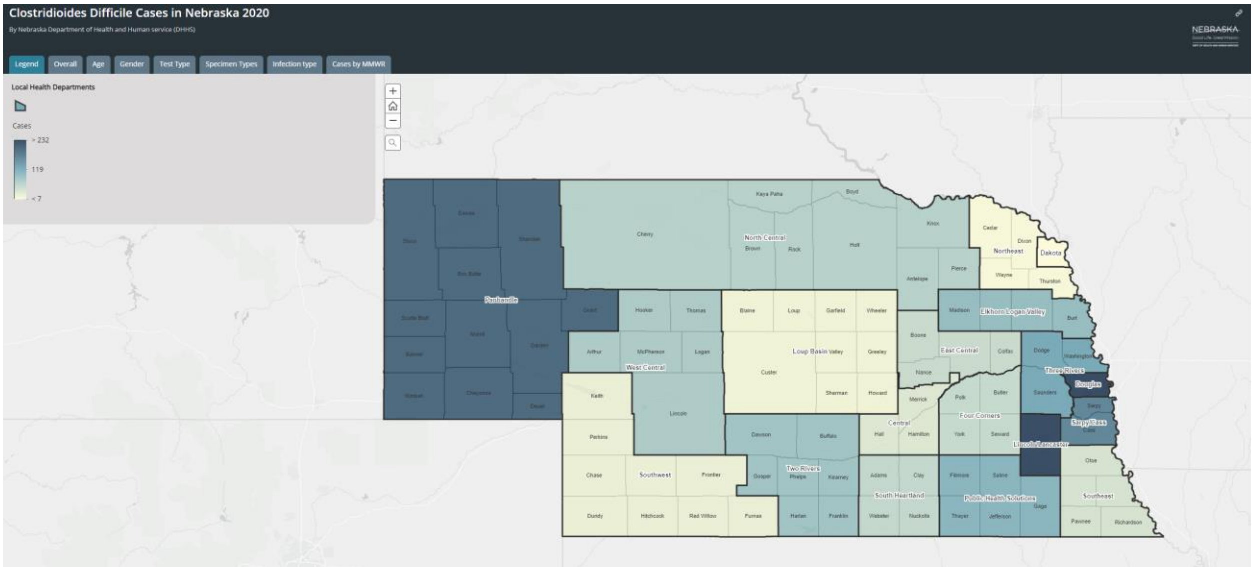

Figure 1. GIS map of 2020 CDI data.

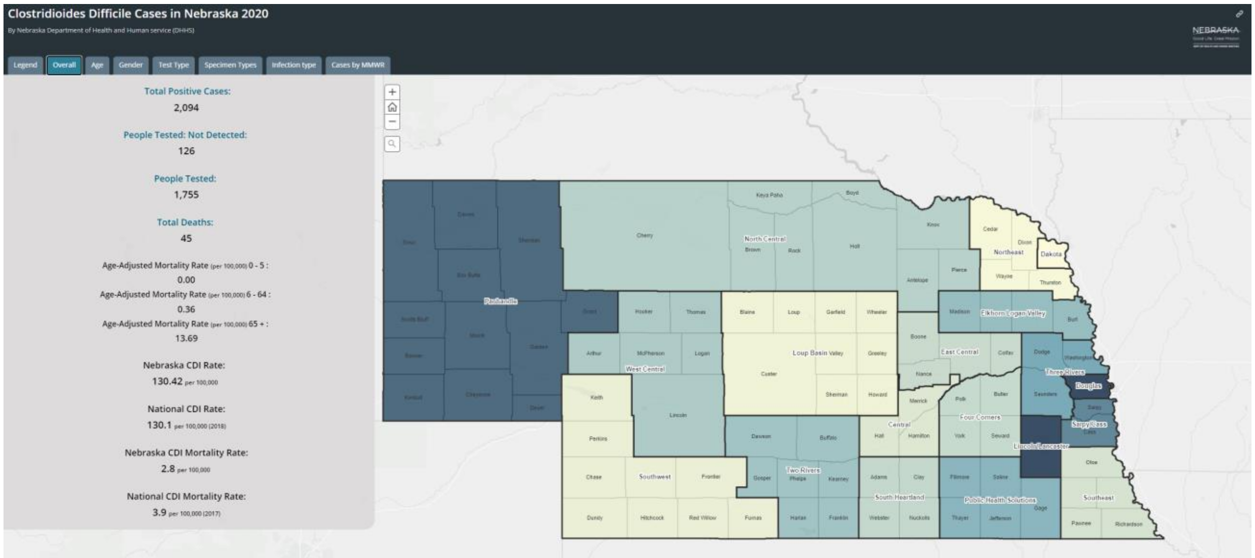

Figure 2. GIS map of 2020 CDI data with overall data

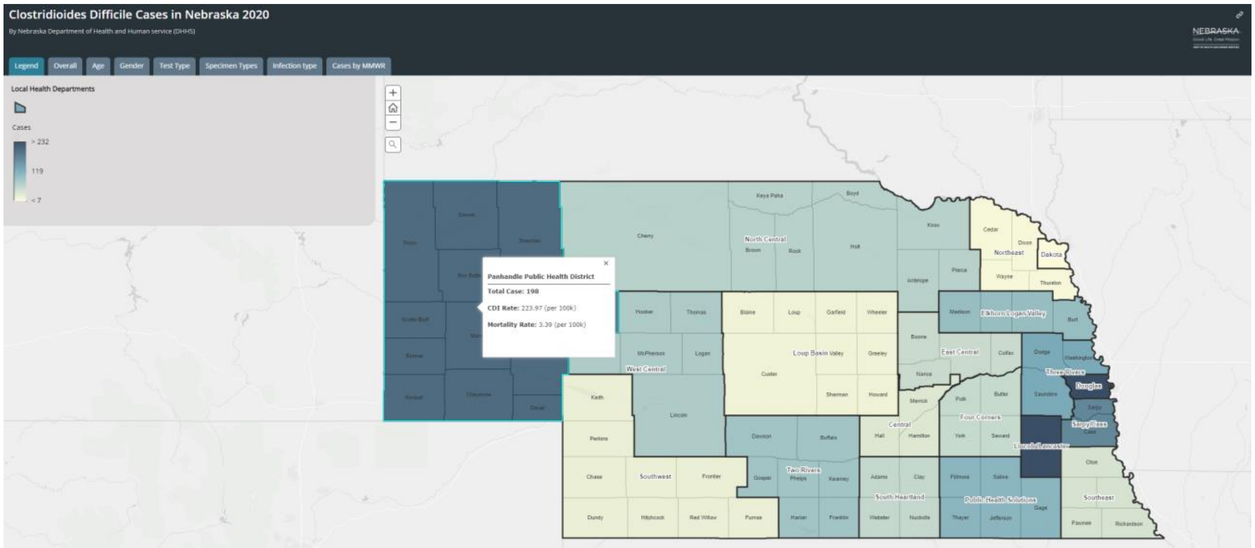

Figure 3. GIS map of 2020 CDI data displaying LHD data.

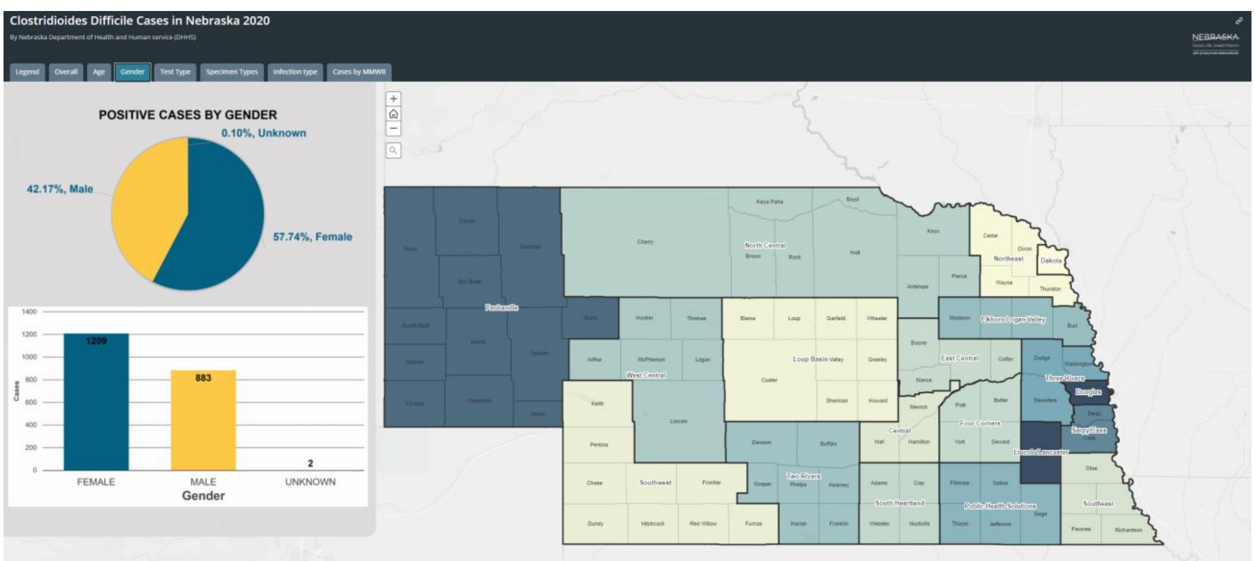

Figure 4. GIS map of 2020 CDI data displaying gender demographics.

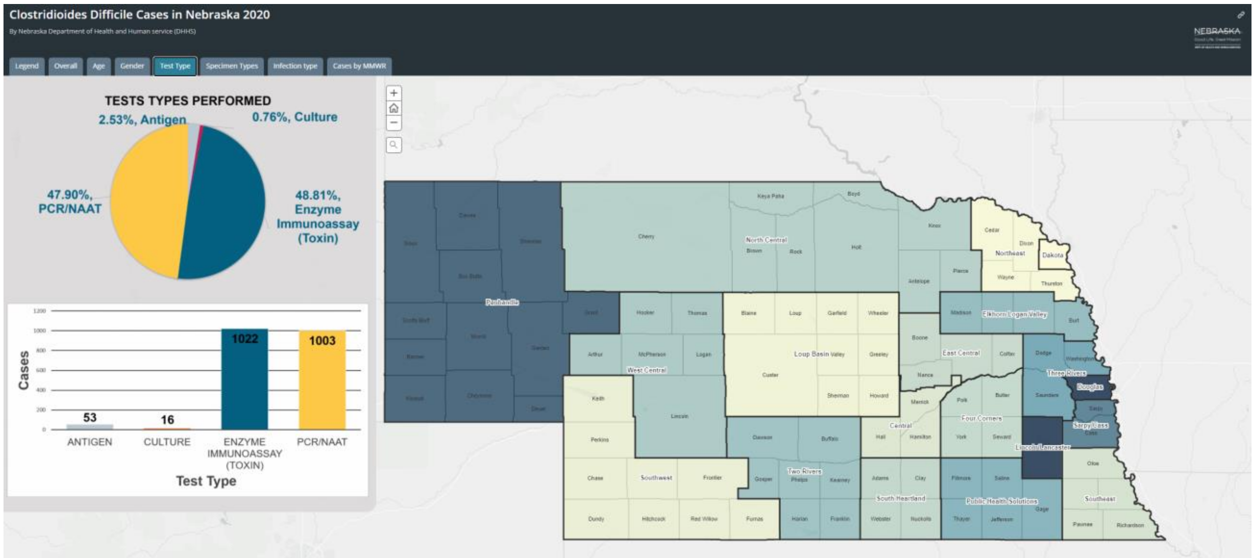

Figure 5. GIS map of 2020 CDI data displaying test type demographics.

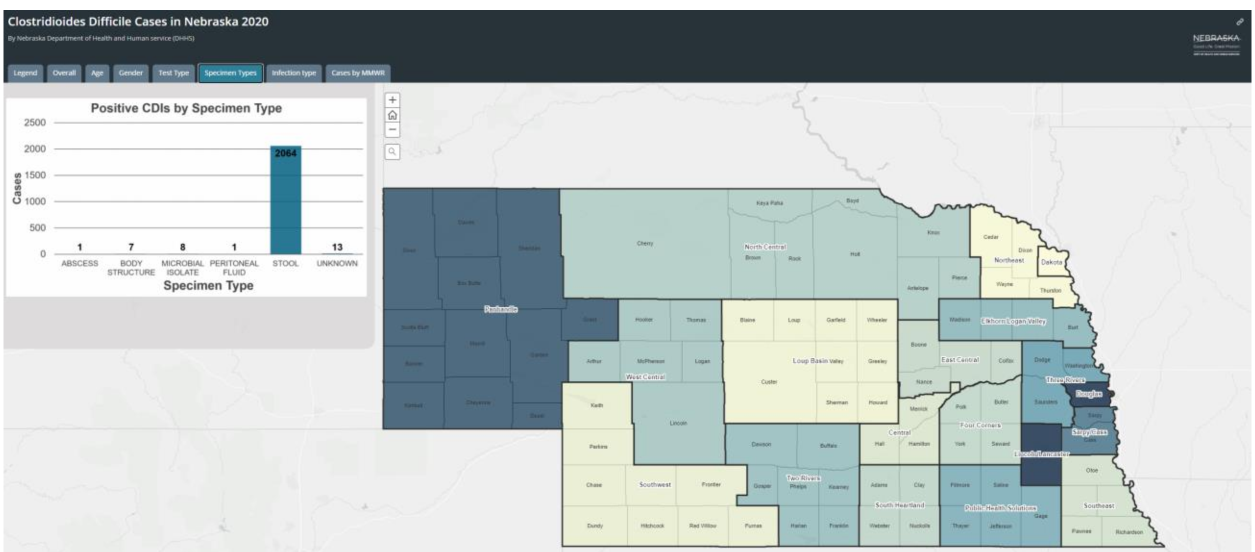

Figure 6. GIS map of 2020 CDI data displaying specimen type demographics.

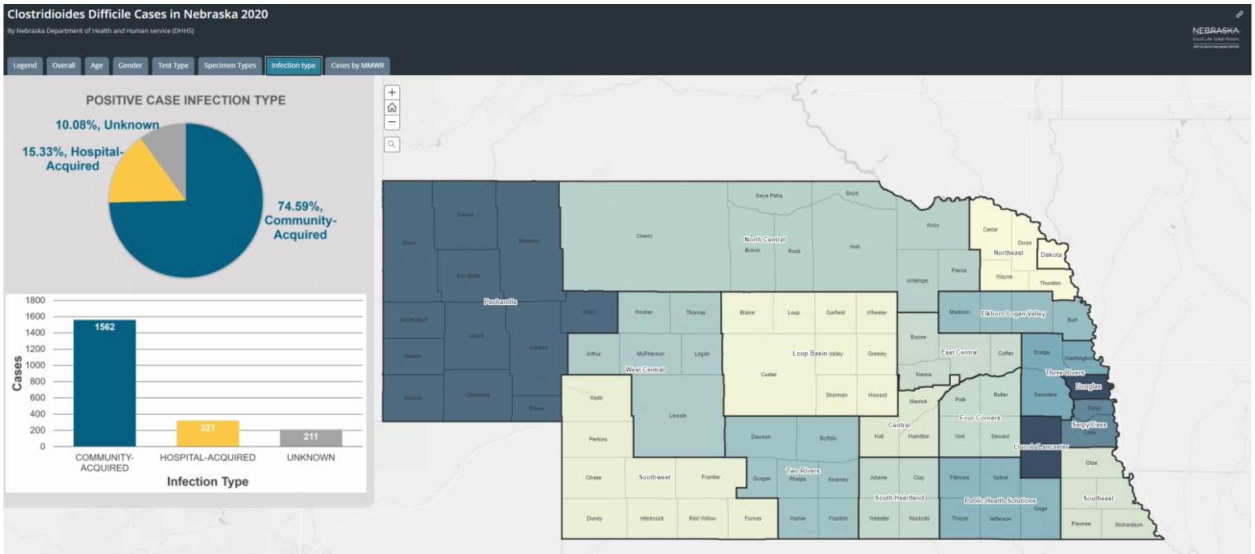

Figure 7. GIS map of 2020 CDI data displaying infection type demographics.

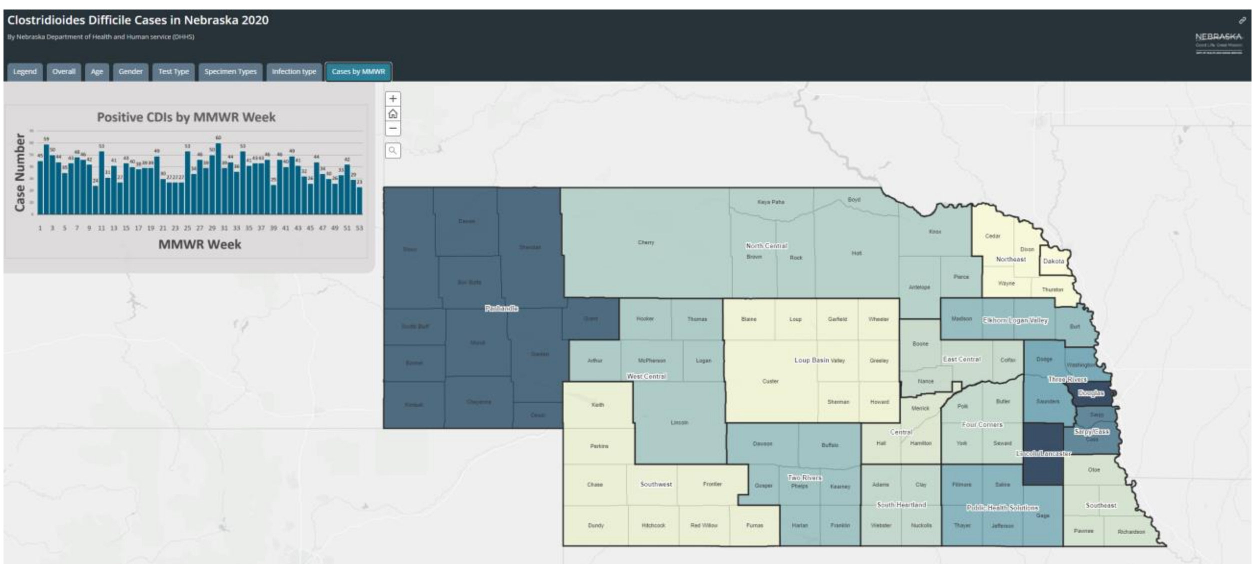

Figure 8. GIS map of 2020 CDI data displaying case by MMWR data.

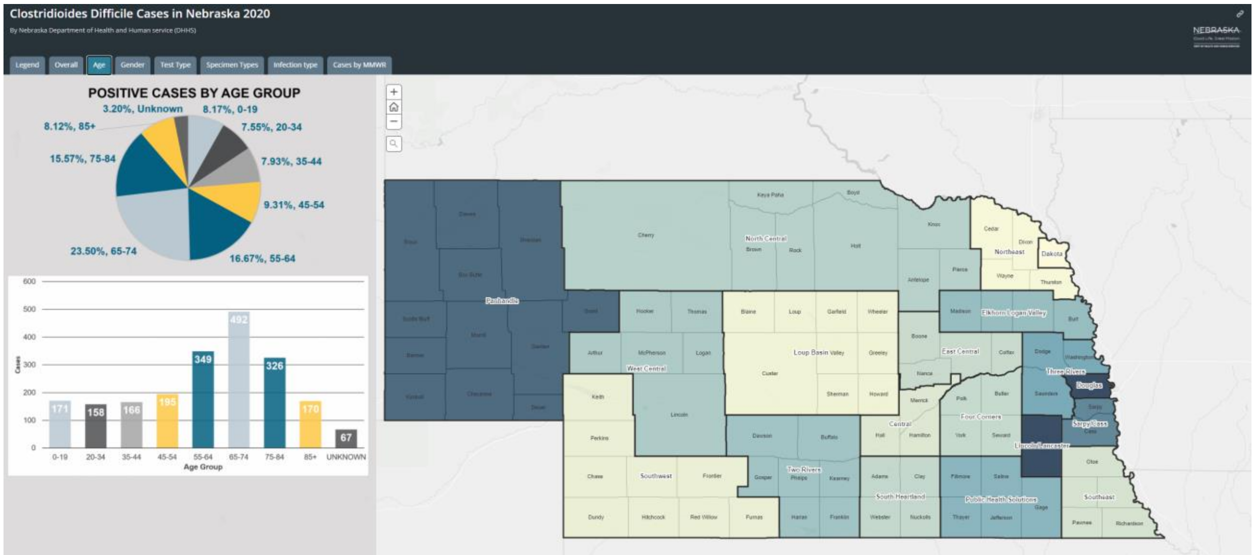

Figure 9. GIS map of 2020 CDI data displaying age demographics.

Appendix E

Storm Keffer

College of Public Health, Epidemiology Department

University of Nebraska Medical Center

Storm is a student at the College of Public Health concentrating in the field of Epidemiology. He graduated from Doane University in 2017 with a degree in biochemistry where he also took a beginner's course on public health just so he could graduate. After graduating he took a year off from school and worked in the human genetics lab as a cytogenetic technologist at UNMC. In 2018, he applied to the epidemiology program at the College of Public Health and has loved that decision since. His interests including antibiotic resistance, infectious diseases, emerging diseases, emergency preparedness, biocontainment, and bioterrorism. He has worked with the MS clinic at UNMC to address health disparities for those with MS, worked on helping with development of a Nebraska pandemic plan, and is a founding member for the student One Health group at UNMC. He hopes to pursue a PhD once he obtains his MPH degree.

STORM KEFFER, MPH

Dedicated epidemiologist with profound interest in healthcare-acquired and multidrug-resistant disease. Experienced in managing investigations, collecting field data, and writing authoritative reports. Proficient in tracking and containing infections. Fastidious and resilient with excellent critical thinking skills and desire to contribute expertise to developing and implementing solutions. Demonstrated success in public health project and team management, including epidemiology, statistical analysis, and literature reviews. Skilled in technical writing, surveillance, and field research. Results-driven and proactive with a diligent, responsive, and resourceful nature.

301 Centennial Mall S
Lincoln, NE 68508

3rd Floor
storm.keffer@nebraska.gov
o 531-530-7407 c 402-547-1008

Last Updated: 2021.04.25

Education

MPH (Epidemiology), University of Nebraska Medical Center 2018-21
BS (Biochemistry), Doane University 2012-17

Academic Projects and Achievements

APEX, Department of Neurological Sciences – Multiple Sclerosis (MS) Clinic, University of Nebraska Medical Center
May 2020 to August 2020

Specific duties and accomplishments

- Attended clinical sessions with MS providers. Sessions included house calls, transdisciplinary clinic and community partnership program, and telemedicine visits
- Identified and created data repository to arrive at estimates of the number of individuals with MS and significant disabilities
- Contributed to the strategic planning of identifying stakeholders who are interested in the field of disability/disparities/social determinates, and health care
- Assisted in creating awareness in the community for individuals with MS
- Developed a policy brief that highlights keep issues faced by those with MS as well as solutions

Capstone, Nebraska Department of Health and Human Services, Public Health Division
August 2020 to May 2021

Specific duties and accomplishments

- Defined the epidemiology of *Clostridioides difficile* in Nebraska between 2018-2020
- Described the demographical data of all *Clostridium difficile* infection (CDI) cases in Nebraska
- Determined the efficacy of Nebraska's antimicrobial stewardship programs by assessing trend data between 2018-2020
- Attempted to discover other potential at-risk populations outside the healthcare and long-term care facility realms by using the social vulnerability index (SVI)
- Created a geographic information system (GIS) map designed to convey the most up-to-date CDI information for future monitoring. This map will be used as a template for all healthcare-acquired diseases (HAIs) in Nebraska
- Created a SAS code used as a template to identify all (HAIs)
- Identified over 600 medical facilities, nursing homes, rehabilitation centers, assisted living facilities, and skilled nursing facilities in the state of Nebraska
- Created a foundational solution to enhance outbreak response and display real time disease information

<u>Appointments and Positions</u>

Heath Surveillance Specialist, Nebraska Department of Health and Human Services (NDHHS), Public Health Division
June 2020 to *present*

NDHHS Public Health is the state appoint division to assist and help all Nebraskans in public health matters across the state. This division is responsible for preventive and community health programs and services. It is also responsible for the regulation and licensure of health-related professions and occupations, as well as the regulation and licensure of health care facilities and services.

Specific duties and accomplishments

- Contact tracing team lead and liaison between the state department, Douglas County Health Department (DCHD), and third-party contact tracing vendor Professional Research Consulting (PRC)
- Assisted in creation and training of contract tracing techniques and SOPs with third-party contact vendors
- Developed an efficient method to record COVID hospitalizations *Epidemiological work in COVID hospitalization outcomes still ongoing*
- Assisted in establishing new contact tracing software move from REDcap to SalesForce

Subject Matter Expert *(volunteer)*, Pandemic Planning Leadership Team, University of Nebraska Medical Center
January 2020 to June 2020

The Pandemic Planning Leadership Team was created by UNMC to oversee several committees in the preparation of the impending COVID pandemic for both UNMC and the state of Nebraska

Specific duties and accomplishments

- Revised the UNMC Pandemic Plan tailored specifically to COVID
- Served each committee on the team as a point of information for them to adequately plan for COVID pandemic
- Created basic "best guess" epidemiology of COVID during Wuhan outbreak to determine future burden on the state of Nebraska
- Calculated potential future burn rates of personal protective equipment (PPE) and inventory
- Assisted in creation of personnel tracker and morgue reports
- Developed predicted UNMC hospital resource usage and predicted COVID outcomes for Douglas County
- Developed state, UNMC, and various other hospital COVID caseload and death predictions using gamma distribution. Depicted the role of mitigation or "flattening the curve" of COVID on hospital surge capacity and its importance in Nebraska
- Assisted in information gathering in the creation of UNMC's COVID dashboard
- Assisted in sample collection, literature review, and data management of project in determining COVID in wastewater.
- Participated in presentations demonstrating basic knowledge of COVID and diseases in addition to potential burdens of COVID on the community of Nebraska

Cytogenetic Technologist, Munroe-Meyer Human Genetics Lab (HGL), University of Nebraska Medical Center
July 2017 to February 2020

UNMC HGL combines comprehensive genetic testing with personalized clinical consultation to provide the very best in genetic medicine to every client and patient

Specific duties and accomplishments

- Perform tissue culture & DNA extraction on human samples
- Prepare G-banded slides and hybridize DNA probes for analysis of genetic disorders
- Use bright field and fluorescent microscopes with a computer imaging system to prepare karyotypes and digitized fluorescence in situ hybridized (FISH) images
- Interpret and summarize karyotypes and FISH results and write cytogenetic and molecular cytogenetic reports for patient diagnostic purposes

- Developed procedural use of ROBOSEP for lymph node and bone marrow core samples
- Developed more efficient way of freezing patient samples. Decreasing time to perform task exponentially

Interventionalist *(volunteer)*, Occupational/Physical Therapy Department, University of Nebraska Medical Center
June 2015 to August 2015

Specific duties and accomplishments

- Communicate, participate in activities that incorporated the Hand Arm Bimanual Intensive Therapy (HABIT) guidelines, and monitor progress in children with Hemiplegic Cerebral Palsy
- Exhibited progress in patient motor functioning in both fine and gross motor skills