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The Impact of the Covid-19 Pandemic on Device-Associated Healthcare-Associated Infections in Nevada

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THE IMPACT OF THE COVID-19 PANDEMIC ON DEVICE-ASSOCIATED HEALTHCARE-ASSOCIATED INFECTIONS IN NEVADA

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Abstract

Healthcare-associated infections or hospital-acquired infections (HAIs) have remained prevalent despite the growth of infection control programs in healthcare facilities and are a large cause of morbidity and mortality. Device-associated HAIs (DA-HAIs) make up a large portion of HAIs. The devices include central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), and ventilator-associated events (VAEs). DA-HAIs became a large concern during the COVID-19 pandemic as many healthcare facilities became overwhelmed by the influx of COVID-19 cases, illuminating the importance of studies to examine these changes. Therefore, this study aimed to evaluate how DA-HAI rates have changed during and after the COVID-19 pandemic in Nevada and how device utilization has influenced this change. This study utilized a cross-sectional analysis design, including data from the National Healthcare Safety Network (NHSN) on CLABSIs, CAUTIs, and VAEs from January 1, 2018, to March 31, 2024, in Nevada. The study has three defined periods: pre-pandemic/baseline (2018-2019), the pandemic period (2020-2022), and post-pandemic (2023-2024). Results indicated that VAEs significantly increased during the pandemic period and have remained high in the post-pandemic period. There was no change in CAUTIs throughout the three periods. A period change was observed in CLABSIs, but only in acute care hospitals. Device utilization was a significant predictor for VAEs and in some healthcare settings for CLABSIs. Differences were also noted in bed size and geographical location in Nevada for some healthcare settings. Understanding the effect of the COVID-19 pandemic can help improve and sustain infection control programs to respond to future pandemics.

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Chapter 1: Introduction

1.1 Background

Historically, hospitals were considered dangerous places for patients as very little was known about pathogen transmission. Mortality in hospitals was high as the facilities were dirty, filled with infection, and not well-ventilated (Smith et al., 2012). Patients would be admitted for a mild condition and often acquired a more complex nosocomial infection during their hospitalization (Smith et al., 2012). Although great advances in knowledge of infectious diseases occurred, treatment and prevention did not arise until about the mid-1800s. At this time, evidence began to demonstrate that healthcare workers could transmit disease between patients (Dixon, 2011; Smith et al., 2012). Public health efforts continued to increase in the 1940s as more knowledge on the spread of infectious diseases became available and more widely accepted. Such efforts included the use of antibiotics, new treatments, and the development of the Centers for Disease Control and Prevention (CDC) (Smith et al., 2012). Infectious disease incidence and mortality were declining, and antibiotic usage was a new phenomenon on the rise (Smith et al., 2012). Infection control programs began to increase as well and were implemented in hospitals in the 1950s (Sydnor & Perl, 2011). These programs entailed the appointment of infection control nurses (ICNs), educating health professionals on hygiene, as well as disease surveillance (Smith et al., 2012).

Despite the growth of infection control programs, healthcare-associated infections, or hospital-acquired infections (HAIs) remain prevalent. HAIs are infections that a patient acquires during their stay at a healthcare facility. An infection is classified as an HAI when the date of onset is on day three and onwards of stay at a healthcare facility (CDC, 2024b). In the U.S., it is estimated that one in 31 patients has at least one HAI on any given day (CDC, 2024b).HAIs are a large cause of morbidity and mortality, with upwards of 15% of patients contracting an infection during hospitalization (Septimus & Moody, 2016). In the U.S., this would account for about 1.7 million HAIs and over 98,000 deaths annually equating to about one in 17 patients dying due to HAIs (Haque et al., 2018; Septimus & Moody, 2016). HAIs are one of the top ten leading causes of death in the US and the most common healthcare complication (Haque et al., 2018). The European Centre for Disease Prevention and Control (ECDC) reported that 3.2 million patients contracted HAIs in European Union (EU) countries, of which 37,000 deaths are recorded each year (Dadi et al., 2021). HAIs reported in intensive care units (ICUs) in developed countries ranged from 5-10%, while in developing countries it was as high as 50% (AlSaleh et al., 2023). Many factors contribute to HAIs, such as patient-related factors (e.g., age and comorbidities) and healthcare-related factors (e.g., the use of invasive devices) (AlSaleh et al., 2023).

Device-associated HAIs (DA-HAIs) make up a large portion of HAIs. The DA-HAIs include central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), and ventilator-associated events (VAEs). CLABSI occurs when a microorganism enters the bloodstream through a central line causing an infection (National Healthcare Safety Network [NHSN], 2024). A central line is defined as an intravascular catheter that terminates at or close to the heart or in one of the great vessels and is used for blood withdrawal, hemodynamic monitoring, or an infusion (NHSN, 2024). There are two types of central lines, temporary and permanent (Haddadin et al., 2024). Permanent lines are tunneled catheters that are surgically implanted for long-term use such as for hemodialysis or chemotherapy (Haddadin et al., 2024). Temporary lines, which are non-tunneled and inserted percutaneously, account for most CLABSIs (Haddadin et al., 2024). CAUTI involves an infection in the urinary system and the patient must have a current indwelling catheter or it was removed the day of or one day before the date of infection (NHSN, 2024). An indwelling catheter is defined as a drainage tube inserted into the urinary bladder via the urethra that is left in place and connected to a drainage bag (NHSN, 2024). VAEs are identified through a combination of criteria: deterioration in respiratory status after a period of stability or improvement on the ventilator, infection or inflammation evidence, and lab evidence of a respiratory infection (NHSN, 2024). To meet the case definition for a VAE the patient must be on a ventilator which is a device used to assist, control, or support respiration delivered through an artificial airway like an oral/nasal endotracheal or tracheostomy tube (NHSN, 2024).

Having a clear understanding of the DA-HAIs it is important to note that those admitted to the ICU are greatly impacted by these infections. In a Poland study following NHSN definitions, it was found that for patients admitted to the ICU, roughly 24.3-27.6% (95% CI, 21.5-27.4) are affected by DA-HAIs (AlSaleh et al., 2023). A separate study found that one in five patients has a DA-HAI which equated to an additional financial burden of 10,000 euros for each patient (Dadi et al., 2021). A 2015 study in Southeast Asia demonstrated a prevalence of VAE of 14.7/1000 ventilator days, CLABSI of 4.7/1000 central line days, and CAUTI of 8.9/1000 catheter days (Izadi et al., 2020). A study in China demonstrated prevalences of VAE of 7.92/1000 ventilator days, CLABSI of 0.63/1000 central line days, and CAUTI of 2.06/1000 catheter days (Izadi et al., 2020). A retrospective study in Saudi Arabia in 2022 found the VAE rate at an adult medical-surgical ICU to be 3.36 per 1000 ventilator days (AlSaleh et al., 2023).Patients in the ICU with a CLABSI have an average of an extra two-week length of stay and 5-30% excess mortality (Alsaffar et al., 2023). On the other hand, ICU patients with a CAUTI have an average of an extra two-week length of stay and 1-13% excess mortality

(Alsaffar et al., 2023). Furthermore, CLABSI and CAUTI complications can incur an additional cost of up to $58,614 and $896 per patient, respectively (Hyte et al., 2023). In addition, 12-16% of adults admitted to the hospital will at some point need an indwelling catheter, thus increasing CAUTI risk by 3-7% per day (Hyte et al., 2023).

1.2 COVID-19 Pandemic Background

Coronavirus-2019 (COVID-19) took the world by surprise with its rapid global spread. This virus is an RNA coronavirus that belongs to the family of Coronaviridae (Wang et al., 2020). It was named SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) and later as COVID-19. Its name was derived due to its similarities to the other viruses in the Coronaviridae family with over 80% similarity with SARS-CoV (Severe Acute Respiratory Syndrome Coronavirus) and 50% similarity with MERS-CoV (Middle East Respiratory Syndrome Coronavirus) (Thompson et al., 2020). Both viruses were responsible for epidemics occurring in the past two decades with high mortality rates (Thompson et al., 2020).

COVID-19 was first reported in Wuhan, China in December 2019 (Thompson et al., 2020). It was described as an atypical pneumonia-like illness (CDC, 2023a). The source of the virus is theorized to have come from the natural reservoir of coronaviruses, bats, that were a part of the unregulated seafood market in Wuhan which may have led to the infection (El-Sayed & Kamel, 2021; Platto et al., 2021). From there, the virus quickly spread throughout China and its neighboring countries (Khan et al., 2021). By January 20th, 2020, the first confirmed case of COVID-19 was reported in the U.S. (CDC, 2023a). COVID-19 was officially declared a pandemic by the World Health Organization (WHO) on March 11th, 2020 (Khan et al., 2021). By November 2020, the U.S. had the highest number of cases (9.8 million) and deaths (239,842) in COVID-19-related cases (Khan et al., 2021). As of April 2024, the U.S. had reported a total of

103 million cases and 1.2 million deaths to the WHO since the beginning of the COVID-19 pandemic (WHO, 2024).

1.3 Impact of the COVID-19 Pandemic on Healthcare Facilities in the US

Healthcare facilities in the US were ill-equipped to handle the COVID-19 pandemic. It placed a huge strain on the healthcare system which resulted in facilities modifying their patient care practice routines that impacted both the healthcare workers and the patients. Hospitals were primarily focused on staying afloat as the pandemic brought about new and unique challenges and magnified any previous challenges within the healthcare system itself (Grimm, 2021).

The pandemic caused a huge strain that left healthcare workers with an increase in workload. The staff had increased hours and responsibilities which led to extra shifts and overtime (Grimm, 2021). Many workers were pulled from their normal duties to handle COVID-related duties (Grimm, 2021). Infection preventionists (IPs) were overwhelmed with COVID-19 duties and had difficulty maintaining infection control programs (Rebmann et al., 2021b). This was compounded for rural IPs, as they have many roles such as infection prevention, quality control, and occupational health (Rebmann et al., 2021b). IPs prioritize the response to the pandemic over standard infection prevention practices (Rebmann et al., 2021a). Without focusing on preventing infections there could have been a chance for HAIs to increase during this time (Rebmann et al., 2021a). It became difficult to maintain infection prevention and control (IPC) programs (Alsuhaibani et. al., 2022). In addition, a decrease in surveillance occurred in the second quarter of 2020 compared to the same period in 2019 which could have contributed to higher HAI rates (Rebmann et al., 2021b). Multiple IPs reported seeing an increase in HAIs and mentioned staff turnover as a contribution (Rebmann et al., 2021b). Furthermore, it was mentioned that many nurses quit during the pandemic and new nurses were recruited (Rebmann et al., 2021b). In addition, hospitals reported staff shortages which directly affected patient safety and quality of care (Grimm, 2021). One hospital administrator reported their hospital had reduced staff-to-patient ratios during the pandemic which can lead to mistakes as patient attention was reduced (Grimm, 2021). A systematic review found a statistically significant link between staffing issues during the pandemic and the risk of acquiring an HAI (Rebmann et al., 2021b). Furthermore, one hospital reported an increase in CLABSIs which can be life-threatening, attributing this increase to insufficient staffing and staff fatigue (Grimm, 2021).

Many changes in practices within the healthcare system occurred in addition to staffing issues. Many IPs discussed the challenges that the pandemic brought upon the healthcare staff such as fatigue. According to IPs, fatigue led to the healthcare personnel requiring reminders and re-education on basic infection HAI prevention (Rebmann et al., 2021b). This could have led to an increase in HAIs during the pandemic as staff were burnt out with the increased duties. Furthermore, staff would make clinical decisions they thought would decrease COVID-19 exposure but posed a risk for the development of an HAI (Rebmann et al., 2021a). For instance, physicians tried to put central lines in the groin as they believed it would be safer for nurses instead of being near a patient's head, which could increase HAI risk (Rebmann et al., 2021a). This could have increased the risk for HAIs as there is more skin flora Furthermore, many essential procedures were overlooked due to limiting the number of healthcare workers going into patient rooms to limit exposure, such as oral care, daily baths, and changing IVs (intravenous therapy (Rebmann et al., 2021a).

Hand hygiene compliance (HHC) was difficult to maintain even during the pandemic. HHC reached higher levels than normal at the beginning of the pandemic but began to decline soon after (Moore et al., 2021). Conservation of hand hygiene products and personal protective equipment (PPE) may have played a role in the decrease in hand hygiene opportunities (Moore et al., 2021). There were fewer direct observations and reminders to healthcare personnel to perform hand hygiene due to the shift in priorities to the pandemic (Moore et al., 2021). HHC was very low at 46% pre-pandemic and as low as 34% during the pandemic (Stangerup et al., 2021). Furthermore, HHC increased when the initial shutdown for COVID-19 occurred and again in December 2020 when new guidelines from the government were enforced (Stangerup et al., 2021). It was found that HHC was higher after patient contact compared to before patient contact (Stangerup et al., 2021). Such a low compliance with hand hygiene can facilitate the spread of pathogens within a healthcare facility which could increase the risk of acquiring an HAI.

Chapter 2: Background and Significance

2.1 Literature Review

Device HAIs became a large concern during the COVID-19 pandemic as many healthcare facilities became overwhelmed by the influx of COVID-19 cases. Facilities had to navigate managing these pandemic cases while providing essential care to non-COVID cases (Teus et al., 2024). Healthcare facilities continued to input their data on HAIs into the National Healthcare Safety Network (NHSN) which captured the number of HAIs occurring throughout the COVID-19 pandemic in the U.S. Increases in the standardized infection ratio (SIR) for CLABSIs, CAUTIs, and VAEs were reported (Evans et al., 2022). When comparing 2020 to 2019 data in the U.S., the most pronounced upward trend in SIRs was found in CLABSI; however, this was more pronounced in the early months of the pandemic (Rosenthal et al., 2022).

2.1.1 Central Line-Associated Bloodstream Infections (CLABSI)

Trends in CLABSI from the pre-pandemic to the pandemic period mainly showed increases. In a study examining the Southeastern US from January 2018 to March 2021, CLABSI rates increased significantly from 0.6 to 0.9 per 1000 central line days (Advani et al., 2023). Central line days refer to the total number of days a central line was in place for all patients in a facility (NHSN, 2024). The greater the number of central line days the greater the chance for a CLABSI to occur (NHSN, 2024). Significant increases in mean central line days were also observed from 937 to 969 (Advani et al., 2023). Another study found a significant CLABSI increase in central line days from 647 to 677 (Advani et al., 2021). A study examining 78 hospitals from a single healthcare system found an increase from 0.56 to 0.85 per 1000 central line days from the pre-COVID-19 to pandemic period, which equated to a 51% increase (Fakih et al., 2021). Furthermore, in ICUs, CLABSI rates increased from 0.68 to 1.16 per 1000 central line days, equating to a 71% increase (Fakih et al., 2021). Patient days also increased during the pandemic period. Patient days refers to the number of patients in an inpatient location during a period of time (NHSN, 2024). There was an increase from 1.00 to 1.64 per 10,000 patient days, which was a 62.9% increase (Fakih et al., 2021). In the ICU, this increase was even larger with a 90.7% increase from 2.95 to 5.63 per 10,000 patient days (Fakih et al., 2021). A study in Texas, though, found the opposite results as there was a decrease in CLABSIs from 0.51 to 0.32 per 1000 central line days (Dib et al., 2023). The Texas study noted that the hospitals had only experienced and trained healthcare personnel doing central line placements and maintenance (Dib et al., 2023). Furthermore, the COVID-19 units were staffed by experienced nurses only (Dib et al., 2023).

There were increases in the central-line standardized utilization ratio (SUR) which is the ratio between the observed device days and the predicted device days (NHSN, 2024). There were increases from 0.88 to 0.92 during the pandemic, equating to a 4.9% increase (Fakih et al., 2021). Device standardized infection ratio (dSIR) also significantly increased during the pandemic from 0.58 to 0.87, a 49.6% increase (Fakih et al., 2021). A dSIR is defined as the ratio of observed infections over the predicted amount of infections (NHSN, 2024). An even more pronounced change was found in the population standardized infection ratio (pSIR) which significantly increased by 58.4% from 0.51 to 0.81 (Fakih et al., 2021). The pSIR is the ratio of observed events over the expected events based on the expected device days in the same population (Fakih et al., 2021). In addition, during the months in which COVID-19 admissions were >10% the CLABSI dSIR was at 1.58 versus when COVID-19 admissions were <5% at 0.67 (Fakih et al., 2021). Furthermore, COVID-19-positive patients were at greater than five times more likely to experience a CLABSI event than those who were COVID-19-negative (Fakih et al., 2021). Subsequently, COVID-19 patients with a CLABSI had significantly higher mortality at 53.8% than those without COVID-19 at 24.0% during the pandemic period (Fakih et al., 2021).

There were also differences in CLABSI events based on healthcare facility type and size. CLABSI rates increased significantly by 48% in community hospitals but not in academic hospitals in the early stages of the pandemic (Advani et al., 2023). In acute care Veterans Affairs (VA) hospitals CLABSI increased significantly from 0.887 to 1.163 per 1000 central line days, a 31% increase and a 3% increase in device utilization (Evans et al., 2022). In contrast, long-term care VA facilities saw no significant changes in CLABSI rates from the pre-pandemic to the pandemic period (Evans et al., 2022). Large hospitals saw increases in CLABSI rates of 60%, an increase from 0.58 to 0.88 per 1000 central line days, and an increase from 1.07 to 1.74 per 10,000 patient days (Baker et al., 2022; Fakih et al., 2021). A study of the Southeastern U.S. though, found CLABSI rates to be stable in large hospitals during the pandemic (Advani et al., 2023). Medium-sized hospitals also saw increases from 0.54 to 0.82 per 1000 central line days, a 6.3% increase in rates, and an increase from 0.95 to 1.61 per 10,000 patient days (Advani et al., 2023; Fakih et al., 2021). One study conducted in 12 states found no significant changes in CLABSI rates (Fakih et al., 2021). However, another study in the Southeastern U.S. found a significant increase of 82.1% in small hospitals at the beginning of the pandemic (Advani et al., 2023). A summary of the CLABSI literature review is in Appendix A: CLABSI Literature Review Tables.

2.1.2 Catheter-Associated Urinary Tract Infections (CAUTI)

In contrast to CLABSI, CAUTI rates seemed to have insignificant changes during the pandemic. CAUTI rates did not change significantly from the pre-pandemic to the pandemic periods (Advani et al., 2021, 2023). One study in Texas found a statistically nonsignificant decrease in CAUTI rates from 0.75 to 0.66 per 1000 catheter (Dib et al., 2023). Another study examining a healthcare system in the U.S. with a pandemic period of March to August 2020, also found nonsignificant decreases from 0.86 to 0.77 per 1000 catheter days (Fakih et al., 2021). On the contrary, acute care VA hospitals saw an increase, though insignificant, a 9% increase of 0.932 to 1.018 per 1000 catheter days, and a 6% increase in device utilization (Evans et al., 2022). A Southeastern U.S. study from January 2018 to March 2021, found there were insignificant increases of 798 to 817 and 675 to 686 in mean urinary catheter days during the pandemic (Advani et al., 2021, 2023). CAUTI dSIR insignificantly decreased during the pandemic from 0.71 to 0.64, and pSIR also insignificantly decreased from 0.58 to 0.57 (Fakih et al., 2021).

Trends in CAUTI did not change in hospital types during the pandemic period (Advani et al., 2023). Large hospital size was associated with greater HAI events, such as a 43% increase in CAUTIs over the span of seven months during the pandemic (Baker et al., 2022). There were no differences in CAUTI rates in the ICUs, but a significant improvement was detected in non-ICU settings from 0.85 to 0.66 per 1000 catheter days (Fakih et al., 2021). A summary of the CAUTI literature review is in Appendix B: CAUTI and VAE Literature Review Tables.

2.1.3 Ventilator-Associated Events (VAE)

VAE trends from pre-pandemic to during the pandemic mainly demonstrated increases. The Southeastern U.S. study found there was a significant rate increase from 6.1 to 10.9 per 1000 ventilator days during the pandemic (Advani et al., 2023). One study of 51 hospitals found an increase in ventilator days but it varied throughout the pandemic period defined as March 2020 to March 2021 (Advani et al., 2021). VAE rates increased by 34% at the start of the pandemic period (Advani et al., 2023). On the contrary, in a study in Texas VAE rates insignificantly decreased from 3.10 to 1.82 per 1000 ventilator days during the pandemic period (Dib et al., 2023). It was explained in the Texas study that the COVID-19 wards were staffed by experienced nurses which could explain the decrease in VAEs (Dib et al., 2023). The mean number of ventilator days significantly increased from 210 to 281 and from 156 to 215 during the pandemic period (Advani et al., 2021).

Differences were seen by hospital type and size. There was a significant increase in VAEs of 41.4% in community hospitals but no change in academic hospitals during the pandemic (Advani et al., 2023). Acute care VA hospitals saw a significant 73% increase in VAEs from 4.501 to 7.808 and an increase in device utilization of 26% (Evans et al., 2022). On the contrary, there were no significant changes in long-term care VA facilities (Evans et al., 2022). VAE rates remained stable in large hospitals but increased by 48.7% in small hospitals and by 104% in medium-sized hospitals at the start of the pandemic defined as phase one from March 2020 to June 2020 (Advani et al., 2023). A summary of the VAE literature review is in Appendix B: CAUTI and VAE Literature Review Tables.

2.2 Study Significance and Gaps in Knowledge

HAIs have continued to occur even with the advances in infection control and prevention. It is crucial to calculate the rates at which these infections occur to identify any gaps in the current protocols and to minimize infections. When major events occur, such as the COVID-19 pandemic, gaps in infrastructure including the healthcare industry are susceptible to the threat of these infections. The COVID-19 pandemic contributed to changes in the incidence of DA-HAIs in the U.S., illuminating the critical need for studies to determine what may have contributed to these increases or decreases and whether it has continued beyond the main surge of the pandemic. This study to our knowledge is the first to examine the changes in rates of CLABSI, CAUTI, and VAE in Nevada from pre-, during, and post-pandemic. Understanding how the pandemic has changed DA-HAI rates is vital in promoting better infection control and prevention practices in Nevada and beyond. Moreover, studies in the literature review only compared the pre-pandemic period to the beginning period of the pandemic itself beginning in either March 2020 or July 2020 and spanning anywhere from August 2020 to March 2022 (Advani et al., 2021, 2023; Baker et al., 2022; Dib et al., 2023; Evans et al., 2022; Fakih et al., 2021). In addition, existing studies do not provide much information on VAEs. Furthermore, reasons behind the changes in the device HAIs are limited in the literature despite the importance it would highlight.

Chapter 3: Methods

3.1 Aims and Hypotheses

Healthcare-associated infections (HAIs) continue to occur despite medical and technological advances. HAIs contribute to increased length of stay, complications, cost, and mortality (Alsaffar et al., 2023; Hyte et al., 2023). Bringing the COVID-19 pandemic into the mix has illuminated the cracks in healthcare facility infection control. Thus, more studies are needed to examine the impact of the pandemic on healthcare facilities and the rates of HAIs in these facilities. Therefore, this study aims to evaluate how device-associated HAI rates changed during and after the COVID-19 pandemic in Nevada. A secondary aim is to determine if device utilization contributed to the increases or decreases in the rates for DA-HAIs. A final aim is to determine if DA-HAI rates differed between Northern and Southern Nevada.

The following research questions will be addressed:

Research Question 1: How have the rates of CLABSIs, CAUTIs, and VAEs changed in Nevada from before the pandemic, during the pandemic, and after the pandemic?

> H_0: The rates for (CLABSI, CAUTI, VAE) have remained the same pre-, during, and post-pandemic in Nevada.
>
> H_a: The rates for (CLABSI, CAUTI, VAE) differed between the pre-, during, and post-pandemic periods in Nevada.

Research Question 2: Did device utilization impact the rates of CLABSIs, CAUTIs, and VAEs before, during, and after the pandemic?

H_0: The device utilization will not affect the rates of (CLABSI, CAUTI, VAE) in Nevada.

H_a: The device utilization will affect the rates of (CLABSI, CAUTI, VAE) in Nevada.

Research Question 3: Is there a difference in CLABSI, CAUTI, and VAE rates between Northern Nevada and Southern Nevada?

H_0: There is no difference in (CLABSI, CAUTI, VAE) rates between Northern and Southern Nevada.

H_a: There is a difference in (CLABSI, CAUTI, VAE) rates between Northern and Southern Nevada.

3.2 Study Design

Employing a cross-sectional study design, this study utilized secondary data from the National Healthcare Safety Network (NHSN) on CLABSIs, CAUTIs, and VAEs from January 1, 2018, to March 31, 2024, in Nevada. The data starts in 2018 because there was a change in the information reported to NHSN in 2016 based on the 2015 baseline (CDC, 2023b). This required healthcare facilities to report more information (e.g., information on VAEs and units within healthcare facilities) and for all HAIs to have the same baseline of comparison for any new infections (CDC, 2023b). With this update, VAEs were added as reportable DA-HAIs as no previous data was recorded (CDC, 2023b). For this reason, 2018 was chosen as more facilities would have begun to record VAE data and updated information. The inclusion criteria consisted of all the events from the DA-HAIs of interest. Exclusion criteria consisted of any explicitly stated exclusions on the data sheets that follow the CDC event definitions and any data points of patients under the age of 18. The exclusions are based on the DA-HAI definition and exclusion criteria stated in the NHSN manual created by the CDC that the state of Nevada must adhere to for the data to be counted in the national dataset (NHSN, 2024). The Nevada Division of Public and Behavioral Health (DPBH) is the department that makes the exclusions, therefore that is the basis for the exclusions in this study. The CLABSI dataset was the only one to explicitly exclude some infection events (n=177) without an explanation as to why, but the events follow the CDC NHSN guidelines.

The study area consisted of all the healthcare facilities that reported HAIs in the state of Nevada. The study had three defined periods: pre-pandemic/baseline (2018-2019), the pandemic period (2020-2022), and post-pandemic (2023-2024). In this study, 2018 and 2019 were considered the baseline for the pre-pandemic period as any HAIs that occurred during this time preceded the COVID-19 pandemic. The years 2020-2022 were defined as the pandemic period as that is when the pandemic started and was at its highest numbers of cases and deaths (CDC, 2024a). Although the WHO declared the end of the COVID-19 pandemic in May of 2023 and the White House declaration ended in April of 2023, Nevada Governor Lombardo ended the COVID emergency in January 2023 when he took office (Starbuck, 2023; WHO, 2023). For this reason, the defined periods are based on Governor Lombardo's decision to end the emergency in Nevada. The years 2023 through the first quarter of 2024 are the post-pandemic period; after January 2023, the number of new COVID cases and deaths began to decrease significantly (CDC, 2024a).

3.3 Ethics

The secondary data from human subjects was retrieved from the NHSN website and was de-identified. In addition, the raw data was screened and only the variables of interest were left (e.g., device days, patient days, county, and event counts). The Office of Research Integrity reviewed this study at the University of Nevada, Las Vegas (UNLV). Confidentiality was protected as patient IDs were used for the cases and no names were attached. For this reason, the UNLV Institutional Review Board (IRB) exempted this study. The exemption notice is in Appendix C: IRB Exemption. All material was kept on a UNLV-issued computer that was password-protected.

3.4 Data Source

This study uses the CDC's NHSN data on CLABSIs, CAUTIs, and VAEs in Nevada (NHSN, 2024). The purpose of NHSN is for all the reporting facilities in Nevada to enter their counts for the DA-HAIs, amongst other infection types. The state put all the information from all the facilities into spreadsheets categorized by infection types and rate listings. The researchers obtained raw data for these infections from NHSN, from January 1, 2018, to March 31, 2024. The raw data included variables such as central-line days, urinary catheter days, ventilator days, date of event, facility type, bed size, and event counts.

3.5 Variables of Interest

The dependent variables were CLABSI, CAUTI, and VAE, condensed by organization, location, and year. Rates for these variables were calculated as they were condensed. A variable was added to define the three periods by the years. The data was stratified by facility type: acute care hospitals (ACH), long-term acute care hospitals (LTACH), and rehabilitation hospitals (REHAB). The data was stratified by facility size: small (≤ 200 beds), medium (201-500 beds), and large (≥ 501 beds). The data was also stratified by Northern Nevada and Southern Nevada. Separation by facility type was necessary because the literature showed differences in infection outcomes. For example, acute care VA hospitals saw increases in device HAIs but not in long-term care VA hospitals (Advani et al., 2023; Evans et al., 2022). Facility size was also considered as some of the literature demonstrated significant changes in the device HAIs based on the size of the facility. CLABSI had increased across the board on all facility types, though one study found rates to be stable in large hospitals (Advani et al., 2023; Fakih et al., 2021). CAUTI tended to have no significant changes yet one study found increases in rates in large facilities (Baker et al., 2022). VAE demonstrated increases in small and medium healthcare facilities but stable rates in large facilities (Advani et al., 2023). The categories for the bed sizes were based on previous literature, although they varied in the literature. Most of the articles described small bed sizes from a range of <100 to <249 beds, medium ranged from about 100 to 500 beds, and large facilities ranging from 300+ to 500+ beds (Advani et al., 2023; AlSaleh et al., 2023; Baker et al., 2022; Fakih et al., 2021). Bed sizes were categorized using the aforementioned ranges. The main predictor of this study was device utilization for each dependent variable. Covariates related to the DA-HAIs were considered for the analyses, but preliminary data analyses demonstrated convergence and singularity issues. Furthermore, the data used was population-level data and not individual-level data. Therefore, the only variables added to the analyses were geographical location (Northern and Southern NV), bed size, and period. A list of the variables of interest and research questions can be found in Table 1.

Table 1: Variables of Interest for the Research Questions

Research Questions	Dependent Variable	Independent Variable	Variables of Interest
How have the rates changed throughout the three periods?	Period 2 & 3 - CLABSI, CAUTI, VAE	Baseline - CLABSI, CAUTI, VAE	Period, Bed size, Location
Did device utilization impact rates?	Rate- CLABSI, CAUTI, VAE	Device Utilization - CLABSI, CAUTI, VAE	Period, Bed size, Location
Is there a difference in rates between Northern and Southern NV?	Period 2 & 3 - CLABSI, CAUTI, VAE	Baseline - CLABSI, CAUTI, VAE	Period, Bed size, Location

3.6 Statistical Analyses

Descriptive statistics were calculated by taking totals and means of the variables used for the statistical analyses. CLABSI, CAUTI, and VAE rates were calculated by each year, organization, and location (defined below). In specialty care areas (SCA) for CLABSI, the rates are calculated separately for temporary and permanent lines. An interquartile range (IQR) outlier test was performed to determine if any outliers existed within the dataset, thus a new dataset without the outliers was created. An analysis of variance (ANOVA) with fixed and random effects was performed on the data with and without the outliers to determine whether any differences existed. Based on the outcome, all final statistical analyses used the datasheets with the outliers due to zero saturation. The zeros within the dataset represent no infections occurred at that time. To examine the interaction between period and rate, Zero Inflated Poisson (ZIP) Regression, Poisson Regression, and density plots were performed to determine which Poisson Regressions were more appropriate for which facility type based on the saturation of zeros. A ZIP Regression is a model used to analyze data that has an excess of zeros, it is crucial to use this analysis to avoid skewness within the data (Statistical Methods and Data Analytics, 2024). A ZIP

Regression was performed on ACHs for all DA-HAIs as the density plots demonstrated zero saturation. For all other facility types, a Poisson Regression was performed as there was variation in the event counts and no zero saturation. An ANOVA was conducted on each device HAI on device utilization ratio (DUR), and the rates of the DA-HAIs to determine if DUR can predict the rates at each of the three defined pandemic periods. DUR calculates the utilization of the devices by taking the total device days over the patient days. The variables of bed size and geographical location were added to the tests to determine if there were any differences between the bed sizes and Northern and Southern NV. The contrast statements used to determine the differences in bed size, geographical location, and period were adjusted with the Bonferroni method. R (version 4.4.0) was used for conducting statistical analyses. The significance level was set at 0.05.

Table 2: Rates and Device Utilization Ratio (DUR) for Central Line-Associated Bloodstream Infections (CLABSIs), Catheter-Associated Urinary Tract Infections (CAUTIs), and Ventilator-Associated Events (VAEs)

DA-HAI	Rate	DUR
CLABSI	$\frac{\text{No. of CLABSIs}}{\text{No. of central line days}} * 1{,}000$	$\frac{\text{No. of central line days}}{\text{No. of patient days}}$
CAUTI	$\frac{\text{No. of CAUTIs}}{\text{No. of catheter days}} * 1{,}000$	$\frac{\text{No. of urinary catheter days}}{\text{No. of patient days}}$
VAE	$\frac{\text{No. of VAEs}}{\text{No. of ventilator days}} * 1{,}000$	$\frac{\text{No. of ventilator days}}{\text{No. of patient days}}$

3.7 Study Importance

This study is important as it adds to the literature since the knowledge about how the DA-HAIs have changed because of the pandemic can inform healthcare facilities on gaps in the incidence of HAIs. The results will prompt healthcare facilities to examine infection control and prevention programs, identify any gaps, and implement interventions. In addition, it will deepen the understanding of device utilization to determine if they are necessary or if other options are more appropriate and less invasive, and when the earliest time for removal is to keep infections low. The study may also allow the healthcare facilities to understand how their specific facility type and size is performing. Furthermore, it highlights the differences between Northern and Southern Nevada so that public health efforts can more closely focus on the areas where higher incidence is occurring to reduce DA-HAIs.

There are key differences between Northern and Southern Nevada. Nevada has a unique geography and population distribution making it one of the most geographically under-populated states in the country (United States Census Bureau, 2021). The population density varies throughout the counties in Nevada. The majority (73%) of the population resides in Clark County which is part of Southern Nevada, with Washoe County (Northern Nevada) having the second most population at 15.7% (United States Census Bureau, 2021). There are not many healthcare facilities throughout Nevada, the majority are concentrated in Las Vegas (South) and other small urban cities such as Carson City (North) (United States Census Bureau, 2021). Hospital resources in Nevada for 2020 demonstrated a greater percentage of occupied beds in Southern Nevada and a higher (79% vs 43%) amount of occupied ICU beds than in Northern

Nevada (Messerly, 2020). Of the available ventilators, 56% were in use in Southern Nevada and 30% in Northern Nevada (Messerly, 2020).

Public health officials can utilize the information gathered by the rates of CLABSI, CAUTI, and VAE to address disparities among healthcare facilities to reduce the risk of these infections in future endeavors. In addition, this study helps in the development of healthcare facility-specific interventions to decrease DA-HAIs in vulnerable areas and facilities. The study will contribute to the literature on epidemic/pandemic preparedness so that public health researchers can utilize the information to recreate similar studies and possibly be better prepared for another pandemic. Therefore, it will help influence updates on infection control and prevention protocols in healthcare facilities. In all, this study serves as a great resource and addition to the literature on DA-HAIs and the COVID-19 pandemic.

Chapter 4: Results

Acute Care Hospitals (ACHs) had data from more facilities and counties than all other healthcare facility types (Table 3). There were more device-related infections for VAEs than CAUTIs and CLABSIs. CAUTI had the highest mean patient days for LTACs (764.34) and IRFs (824.87) while CLABSIs had the most device days for ACHs (115.32) and LTACs (402.65).

Table 3: Descriptive Statistics for CAUTI, CLABSI, and VAEs in Acute Care Hospitals, Long-Term Acute Care Hospitals, and Inpatient Rehabilitation Facilities in Nevada from January 2018-March 2024

Variables	Facilities	Total Infections (%)	Mean Device Days (Range)	Mean Patient Days (Range)	Counties
CAUTI					
Acute Care Hospital	40	1458 (8.00)	101.19 (0-1,099)	599.32 (0-3,271)	8
Long Term Acute Care	7	250 (36.33)	291.08 (18-1,099)	764.34 (50-2,963)	2
Inpatient Rehab Facility	14	64 (7.30)	67.24 (0-325)	824.87 (0-2,544)	2
CLABSI					
Acute Care Hospital	43	1523 (8.91)	115.32 (0-1,399)	602.31 (0-3,271)	8
Long Term Acute Care	9	136 (19.02)	402.65 (12-1,399)	763.17 (18-2,963)	3
Inpatient Rehab Facility	14	9 (1.23)	66.01 (0-426)	774.78 (0-2,188)	2
Specialty Care Areas - Temporary Line	8	46 (6.47)	84.16 (0-271)	452.35 (0-902)	2
Specialty Care Areas - Permanent Line	8	47 (6.61)	89.93 (0-272)	452.35 (0-902)	2
VAE					
Acute Care Hospital	38	4968 (8.69)	67.05 (0-1,213)	555.70 (0-3,271)	8

*CAUTI = catheter-associated urinary tract infection; CLABSI = central line-associated bloodstream infection; VAE = ventilator-associated event

4.1 Catheter-Associated Urinary Tract Infection (CAUTI)

In ACHs, there was no difference between the three study periods, indicating infections occurred at similar rates before, during, and after the COVID-19 pandemic (Table 4). However, there was an overall significant difference between northern and southern NV, indicating northern NV had fewer infections ($p<0.0001$). There was also an overall significant difference between large and medium-sized hospitals, with large hospitals having more infections (p<0.0001). In addition, differences were noted between medium and small-sized hospitals, with medium hospitals having fewer infections. No difference was seen in period or geographical location for LTACs. IRFs had no significant difference in period and facility bed size, but there was a significant difference between northern and southern NV, indicating northern NV had a higher rate of infection (Ratio=2.740). The ratio indicates that for every infection event in Southern NV, it is 2.740 times greater in Northern NV.

Table 4: Zero-inflation Poisson (ZIP) Regression and Poisson Regression of Catheter-Associated Urinary Tract Infections in Acute Care Hospitals, Long-Term Acute Care Hospitals, and Inpatient Rehabilitation Facilities in Nevada from January 2018-March 2024

							95% Confidence Limits	
Variables	**Chisq**	**Estimate**	**Ratio**	**SE**	**z-statistic**	**p-value**	**Lower Bound**	**Upper Bound**
ZIP Regression								
Acute Care Hospital								
(Intercept)				0.184	-8.987	<0.0001		
Period	3.537					0.171		
Geographical Location	25.148					<0.0001		
North vs South NV		-0.387		0.069	-5.583	<0.0001	-0.523	-0.251
Bed size	76.874					<0.0001		
Large vs Medium		0.043		0.064	7.569	<0.0001	0.330	0.636
Large vs Small		0.034		0.083	0.406	1.000	-0.166	0.233
Medium vs Small		-0.449		0.070	-6.416	<0.0001	-0.617	-0.282
Poisson Regression								
Long Term Acute Care								
(Intercept)				0.242	0.304	0.761		
Period	1.529					0.466		
Geographical Location	0.096					0.757		
Inpatient Rehab Facility								
(Intercept)				0.586	2.402	0.016		
Period	1.186					0.553		
Geographical Location	7.831					0.005		
North vs South NV			2.740	0.911	3.025	0.003	1.430	5.260
Bed size	2.057					0.357		

The ANOVA showed that device utilization was not a significant predictor for infection rates in CAUTIs for ACH, LTAC, and IRFs (Table 5). However, northern NV had lower device utilization than southern NV overall (p=0.001). Utilization was also higher in large versus medium facilities (p<0.0001) and small facilities (p=0.002). Device utilization did not significantly change throughout the specified periods.

Table 5: Analysis of Variance (ANOVA) of Catheter-Associated Urinary Tract Infections in Acute Care Hospitals, Long-Term Acute Care Hospitals, and Inpatient Rehabilitation Facilities in Nevada from January 2018-March 2024

								95% Confidence Limits	
Variables	**F-value**	**Sum Sq**	**Mean Sq**	**Estimate**	**SE**	**t-statistic**	**p-value**	**Lower Bound**	**Upper Bound**
Acute Care Hospital									
(Intercept)	1.015								
Utilization	0.384	0.900	0.934				0.535		
Period	0.311	5.700	2.846				0.311		
Geographical Location	4.105	10.000	9.978				0.043		
North vs South NV				-0.267	0.132	-2.028	0.043	-0.526	-0.009
Bed size	10.649	51.800	25.884				<0.0001		
Large vs Medium				0.627	0.137	4.589	<0.0001	0.306	0.947
Large vs Small				0.530	0.153	3.470	0.002	0.171	0.888
Medium vs Small				-0.097	0.173	-0.708	0.759	-0.419	0.225
Long Term Acute Care									
(Intercept)	1.179								
Utilization	0.005	0.010	0.001				0.944		
Period	0.277	0.040	0.525				0.759		
Geographical Location	0.020	1.050	0.038				0.887		
Inpatient Rehab Facility									
(Intercept)	2.266								
Utilization	1.331	2.830	2.834				0.253		
Period	0.487	2.070	1.037				0.617		
Geographical Location	1.816	3.870	3.866				0.183		
Bed size	0.267	1.140	0.569				0.766		

4.2 Central Line-Associated Bloodstream Infection (CLABSI)

There was no significant difference in period for LTACs, IRFs, and SCAs (Table 6). However, large SCA facilities with patients with a temporary central line have a higher rate of infection overall than medium-sized facilities ($p<0.0001$; ratio=5.660). In ACHs, there was a significant difference in the period. CLABSI rates were marginally different between the pre-pandemic and post-pandemic periods ($p=0.051$), and a statistically significant difference was observed between the pandemic and post-pandemic periods ($p<0.001$). There was a statistically significant difference between northern and southern NV, with southern NV having higher rates of infections overall ($p<0.0001$) in ACHs. A statistically significant difference was seen in large versus small hospitals ($p<0.0001$) and in medium versus small hospitals ($p<0.0002$), indicating greater infections in large and medium hospitals for ACHs.

Table 6: Zero-inflation Poisson (ZIP) Regression and Poisson Regression of Central Line-Associated Bloodstream Infections in Acute Care Hospitals, Long-Term Acute Care Hospitals, Inpatient Rehabilitation Facilities, and Specialty Care Areas in Nevada from January 2018-March 2024

							95% Confidence Limits	
Variables	**Chisq**	**Estimate**	**Ratio**	**SE**	**z-statistic**	**p-value**	**Lower Bound**	**Upper Bound**
ZIP Regression								
Acute Care Hospital								
(Intercept)				0.191	-9.265	<0.0001		
Period	13.632					0.001		
Period 1 vs Period 2		-0.092		0.052	-1.756	0.237	-0.217	0.033
Period 1 vs Period 3		0.157		0.157	2.385	0.051	-0.001	0.314
Period 2 vs Period 3		0.249		0.249	3.922	0.000	0.097	0.400
Geographical Location	58.585					<0.0001		
North vs South NV		-0.313		0.064	-4.925	<0.0001	-0.437	-0.188
Bed size	17.878					<0.0001		
Large vs Medium		0.075		0.059	1.271	0.612	-0.067	0.218
Large vs Small		0.459		0.061	7.571	<0.0001	0.314	0.604
Medium vs Small		0.384		0.052	7.330	<0.0002	0.258	0.509
Poisson Regression								
Long Term Acute Care								
(Intercept)				0.310	-3.640	0.000		
Period	2.172					0.338		
Geographical Location	1.408					0.235		
Inpatient Rehab Facility								
(Intercept)				3632.486	-0.005	0.996		
Period	1.383					0.501		
Geographical Location	0.730					0.393		
Bed size	1.160					0.560		
Specialty Care Area – Permanent Line								
(Intercept)				0.584	-2.159	0.031		
Period	5.569					0.062		
Geographical Location	2.189					0.139		
Bed size	1.599					0.206		
Specialty Care Area – Temporary Line								
(Intercept)				0.355	0.073	0.942		
Period	0.879					0.644		
Geographical Location	3.297					0.069		
Bed size	20.849					<0.0001		
Large vs Medium			5.660	2.300	4.270	<0.0001	2.550	12.500

In CLABSIs, device utilization was shown to be a significant predictor for the rate of ACHs, LTACs, and SCAs in patients with temporary lines (Table 7). Device utilization did not change throughout the period. There was a significant difference in ACHs between large and medium hospitals (p=0.019), between large and small hospitals (p<0.0001), and between medium and small hospitals (p=0.001). Large hospitals had greater device utilization than medium and small ones, and medium-sized hospitals had more device utilization than small hospitals.

Table 7: Analysis of Variance (ANOVA) of Central Line-Associated Bloodstream Infections in Acute Care Hospitals, Long-Term Acute Care Hospitals, Inpatient Rehabilitation Facilities, and Specialty Care Areas in Nevada from January 2018-March 2024

								95% Confidence Limits	
Variables	**F-value**	**Sum Sq**	**Mean Sq**	**Estimate**	**SE**	**t-statistic**	**p-value**	**Lower Bound**	**Upper Bound**
Acute Care Hospital									
(Intercept)	0.618								
Utilization	32.828	41.400	41.380				<0.0001		
Period	0.871	2.200	1.100				0.419		
Geographical Location	1.523	1.900	1.920				0.217		
Bed size	18.906	47.700	23.830				<0.0001		
Large vs Medium				0.280	0.103	2.715	0.019	0.038	0.522
Large vs Small				0.656	0.114	5.739	<0.0001	0.388	0.925
Medium vs Small				0.377	0.103	3.664	0.001	0.135	0.618
Long Term Acute Care									
(Intercept)	1.50								
Utilization	5.874	3.324	3.324				0.019		
Period	0.245	0.277	0.139				0.784		
Geographical Location	0.975	0.552	0.552				0.328		
Inpatient Rehab Facility									
(Intercept)	-0.116								
Utilization	2.921	1.984	1.984				0.0954		
Period	0.831	0.253	0.126				0.831		
Geographical Location	0.246	0.167	0.167				0.623		
Bed size	0.613	0.672	0.336				0.613		
Specialty Care Area – Temporary Line									
(Intercept)	3.710								
Utilization Temporary Line	9.829	53.300	53.300				0.004		
Period	1.588	17.220	8.610				0.220		
Geographical Location	2.749	14.910	14.910				0.107		
Bed size	4.334	23.500	23.500				0.045		
Large vs Medium				1.84	0.893	2.059	0.048	0.020	3.660
Specialty Care Area – Permanent Line									
(Intercept)	0.407								
Utilization Permanent Line	1.390	91.400	91.390				0.247		
Period	0.658	86.500	43.240				0.525		
Geographical Location	1.556	102.300	102.320				0.221		
Bed size	0.386	25.300	25.350				0.539		

4.3 Ventilator-Associated Event (VAE)

Unlike the other infection types, VAEs had a statistically significant difference in all periods (Table 8). The pre-pandemic period had lower infection rates than both the pandemic ($p<0.0001$) and post-pandemic periods ($p<0.0001$). A statistically significant difference in bed size was observed between large and medium hospitals ($p=0.005$), with large hospitals having fewer infections which was not observed in the other infection types.

Table 8: Zero-inflation Poisson (ZIP) Regression of Ventilator-Associated Events in Acute Care Hospitals in Nevada from January 2018-March 2024

						95% Confidence Limits	
Variables	**Chisq**	**Estimate**	**SE**	**z-statistic**	**p-value**	**Lower Bound**	**Upper Bound**
Acute Care Hospital							
(Intercept)			0.148	-7.515	<0.0001		
Period	324.545				<0.0001		
Period 1 vs Period 2		-1.189	0.073	-16.392	<0.0001	-1.362	-1.010
Period 1 vs Period 3		-0.355	0.090	-3.955	0.000	-0.571	-0.140
Period 2 vs Period 3		0.833	0.092	9.043	<0.0001	0.613	1.050
Geographical Location	0.157				0.692		
Bed size	10.165				0.006		
Large vs Medium		-0.178	0.057	-3.120	0.005	-0.314	-0.041
Large vs Small		0.019	0.175	0.106	1.000	-0.400	0.437
Medium vs Small		0.196	0.175	1.121	0.787	-0.223	0.616

Device utilization was a statistically significant predictor for the rate of VAEs in the ACHs (Table 9). There was no difference noted in device utilization during the periods. There were differences in device utilization in different hospital sizes. There was greater utilization in large hospitals than in medium (p=0.019) and small hospitals (p<0.0001), and in medium hospitals than in small hospitals (p=0.001).

Table 9: Analysis of Variance (ANOVA) of Ventilator-Associated Events in Acute Care Hospitals in Nevada from January 2018-March 2024

								95% Confidence Limits	
Variables	**F-value**	**Sum Sq**	**Mean Sq**	**Estimate**	**SE**	**t-statistic**	**p-value**	**Lower Bound**	**Upper Bound**
Acute Care Hospital									
(Intercept)	0.618								
Utilization	32.828	41.400	41.380				<0.0001		
Period	0.871	2.200	1.100				0.419		
Geographical Location	1.523	1.900	1.920				0.217		
Bed size	18.906	47.700	23.830				<0.0001		
Large vs Medium				0.280	0.103	2.715	0.019	0.038	0.522
Large vs Small				0.656	0.114	5.739	<0.0001	0.388	0.925
Medium vs Small				0.377	0.103	3.664	0.001	0.135	0.618

4.4 Overall Results

Of the three DA-HAIs, VAEs and CLABSI ACHs demonstrated significant rate changes across the three study periods (Table 10). Device utilization was a significant predictor for the rates in VAEs and some CLABSI facilities (i.e., ACHs). For CLABSI and CAUTI, Northern NV had lower rates in ACHs than Southern NV; however, in CAUTI IRFs Northern NV had higher rates.

Table 10: Summary of Research Questions and DA-HAI Results in Nevada, January 2018-March 2024

Infection	Research Question 1	Research Question 2	Research Question 3
Central Line-Associated Bloodstream Infection (CLABSI)	Period change in ACHs	Device utilization had significant rates for ACH, LTAC, and SCAs for temporary lines	There were lower rates in Northern NV in ACHs
Catheter-Associated Urinary Tract Infection (CAUTI)	No period change in any facility	There was no device utilization effect for any facility	ACHs have lower rates in Northern NV and IRFs have higher rates in Northern NV
Ventilator-Associated Event (VAE)	Period change in ACHs	Device utilization had significant rates of ACHs	There was no difference in location for the facility

*Research question 1: How have the rates for CLABSI, CAUTI, and VAE changed during the three study periods?
*Research question 2: Did device utilization impact the rates for CLABSI, CAUTI, and VAE during the three study periods?
*Research question 3: Was there a difference in the rates for CLABSI, CAUTI, and VAE between Northern and Southern Nevada?

Chapter 5: Discussion

5.1 Central Line-Associated Bloodstream Infection (CLABSI)

Interestingly, CLABSI rates did not vary in the three periods (pre-pandemic, pandemic, and post-pandemic) in LTACs, IRFs, and SCAs. The COVID-19 pandemic did not seem to affect the rates as they were shown to have remained the same during all those years. Similarly, another study found a nonsignificant change in CLABSIs in Veterans Affairs (VA) LTAC from before and during the COVID-19 pandemic (Evans et al., 2022). However, a statistically significant difference in the periods was seen in ACHs. The main difference was between the pandemic and the post-pandemic period, indicating the pandemic period had higher rates. This was interesting as there was no difference between periods one and two and a marginal difference between periods one and three. Other studies have found a significant difference in rates between the pre-pandemic and pandemic periods (Advani et al., 2023; Dib et al., 2023; Fakih et al., 2021). These differences could have been due to the severe changes in staff-to-patient ratios during the pandemic.

During the pandemic, there was a lot of staff turnover as many experienced nurses quit and new nurses were recruited, which could have led to mistakes being made (Rebmann et al., 2021b). Staff shortages directly affect patient safety and the quality of the care they receive (Grimm, 2021). COVID-19 impacted the staffing ratios which caused nurses to be redeployed into critical units such as the ICU or temporary ICUs due to the influx of COVID cases (Kennedy et al., 2022). Many of the nurses did not have the experience to take care of critical patients and were given minimal training (Kennedy et al., 2022). In addition, there was a lack of communication between the administration and the nursing staff with the redeployed nurses who were caring for critically ill patients (Kennedy et al., 2022). Errors could have occurred as these nurses were learning on the job during this period. Furthermore, there has been a pre-existing nurse shortage that has been compounded under the pressure of the COVID-19 pandemic (Martin et al., 2023). The high patient-to-staff ratios, workplace safety, and long hours have driven many workers out of the healthcare workforce (Martin et al., 2023).

Device utilization was a significant predictor for the rates of ACHs, LTACs, and SCAs in patients with a temporary line. This suggests that the more invasive confer a risk of infection. On the contrary, IRFs and SCAs in patients with permanent line device utilization were insignificant. Other studies showed an increase in utilization during the pandemic period in ACHs and LTACs (Evans et al., 2022; Fakih et al., 2021). The difference in permanent and temporary lines was interesting as they had almost the same number of infections and similar mean device days at 89.93 and 84.16, respectively. Temporary lines account for the majority of CLABSIs, as it is more likely for skin-dwelling bacteria to migrate to the external surface of the central line (Haddadin et al., 2024). Typically, these infections tend to occur more often due to healthcare provider handling than from the host (Haddadin et al., 2024).

Differences by bed size were only seen in ACHs. Large-sized hospitals had higher rates of infections than small hospitals while medium-sized had higher rates of infections than small hospitals. Other studies found increases in large, medium, and small bed sizes (Advani et al., 2023; Baker et al., 2022; Fakih et al., 2021). A plausible reason could be the staffing issues that have always been there and were exacerbated by the pandemic as larger hospitals need to have more staff (Grimm, 2021). A systematic review found staff issues (e.g., staff turnover, lack of training resources, inexperienced healthcare personnel) to be attributed to the risk of HAIs (Rebmann et al., 2021b). There was a general difference between infection rates between Northern and Southern NV with Northern NV experiencing fewer infections. A plausible explanation could be that there are more and larger hospitals in Southern NV thus Southern NV would have a greater chance of having infections based on the number of admissions and possible device days (United States Census Bureau, 2021).

5.2 Catheter-Associated Urinary Tract Infection (CAUTI)

This study found that CAUTIs had no differences between the three periods. Similarly, other studies found no significant changes in CAUTIs from before to during the pandemic period (Advani et al., 2023; Dib et al., 2023; Fakih et al., 2021). A decrease in surveillance was found to have occurred in the second quarter of 2020 when compared to the same time in 2019 which could have led to the undercount of possible CAUTIs (Rebmann et al., 2021b). A plausible explanation for these findings could be attributed to the difference in hospitalized patient populations during the COVID-19 pandemic (Fakih et al., 2021). There were greater admissions for people who had COVID-19, and fewer surgeries and elective procedures being performed. In addition, there were increases in the use of antimicrobials which could have inadvertently suppressed the presence of bacteriuria that could have sprouted (Fakih et al., 2021). Furthermore, there could have been a reduction in what was a concern to ordering urine cultures such as the color of the urine or its turbidity in efforts to reduce contact with patients (Fakih et al., 2021). There could have also been a shift in testing for COVID-19 in critically ill patients with high fevers rather than having a urine analysis (Advani et al., 2023).

Device utilization was also not a good predictor for the CAUTI rates. This indicates utilization of catheters did not affect the number of infections that occurred. In addition, there was no significant change in device utilization during the three periods. On the contrary, other studies found a significant increase in utilization from before to during the pandemic; however, the rates of CAUTI did not increase (Evans et al., 2022; Fakih et al., 2021). A plausible reason for a lack of change in device utilization could be that patients were dying or being discharged before the need for an indwelling catheter arose.

There were general differences between bed sizes in ACHs. Large and small hospitals had greater infections than medium hospitals. A study found that large hospitals were associated with a greater amount of CAUTIs (Baker et al., 2022). It was interesting to find that small hospitals had a greater infection rate than medium hospitals. This could be attributed to the geography of Nevada itself as the population density varies significantly throughout the state (United States Census Bureau, 2021). Smaller hospitals would get more easily overwhelmed with an influx of patients as they tend to have less staff. Northern NV had fewer infections than Southern NV for ACHs, while Northern NV had more infections for IRFs. Southern NV having more infections in ACHs could be attributed to the significant difference in population, as 73% of the population resides in Southern NV (United States Census Bureau, 2021). Rates in Northern NV for IRFs could have been higher due to having fewer catheter days, which indicates infections were occurring at a faster pace.

5.3 Ventilator-Associated Event (VAE)

VAEs varied throughout the three periods. The pre-pandemic period had fewer infections than the pandemic and post-pandemic periods. Other studies though saw similar results with significant increases in VAEs from before to during the pandemic (Advani et al., 2021, 2023; Dib et al., 2023). A study found that staff would make clinical decisions to reduce their COVID-19 exposure, but this could have posed a risk for the development of HAIs (Rebmann et al., 2021b). Hand hygiene compliance increased at the beginning of the pandemic but quickly decreased to as low as 34% during the pandemic (Stangerup et al., 2021). Hand hygiene was found to be higher after patient contact compared to before patient contact which indicated a greater concern about getting COVID-19 versus spreading pathogens which could have contributed to higher VAEs (Stangerup et al., 2021). Hand hygiene though is something this study was unable to account for as this information was not collected by NHSN. In addition, the influx of patients due to the pandemic led to many healthcare workers experiencing fatigue. This in turn led to these personnel requiring reminders and getting re-educated on basic infection prevention which could have led to a greater amount of VAEs (Rebmann et al., 2021b).

Device utilization was a significant predictor of VAE infection rates, indicating that the greater the utilization of the ventilators the greater the chance for an infection. Similarly, another study found significant increases in device utilization from before to during the pandemic (Evans et al., 2022). Due to the nature of COVID-19, a respiratory disease, many of the patients who were severely ill with COVID-19 had a ventilator placed. There was a huge increase in utilization, many places had shortages of ventilators and choices had to be made on which patients were able to use the ventilator (Dar et al., 2021).

VAEs occurred at different rates by bed size. It was interesting that large and small hospitals had the same number of VAEs. Equally interesting is that large hospitals had fewer infections than medium-sized ones, which was unexpected based on the literature. Other studies found that VAEs in large hospitals remained stable while small (48.7%) and medium-sized hospitals (104%) increased from the periods of January 2018 to March and June 2021 (Advani et al., 2023; Evans et al., 2022). The difference in rates for the hospital sizes could be attributed to the increase in workload due to the pandemic. IPs were overwhelmed with COVID-19-related duties which made it difficult to keep up with their regular duties, which would have been exacerbated in smaller hospitals as they tend to have one to two IPs at most (Grimm, 2021; Rebmann et al., 2021a). Many of the IPs in small and medium hospitals handle many roles apart from infection prevention such as credentialing, quality control, and occupational health (Rebmann et al., 2021a). In addition, IPs were also reassigned during the pandemic to mitigate staffing issues which could have further contributed to the infection prevention lapses (Evans et al., 2022). This would have a larger impact on smaller facilities as the staff is already much lower than in larger facilities while still having to keep up with all the same practices that large facilities have such as infection prevention (Evans et al., 2022). Larger facilities were better equipped with staff and materials, regardless of the staff shortages (Evans et al., 2022). Not being equipped to handle the pandemic could have led to challenges in the quality of care (Grimm, 2021). With reduced staff-to-patient ratios, less attention to the patients can lead to mistakes (Grimm, 2021). In addition, hiring staff not fully trained in the hospital's infection control and prevention protocols could have contributed to the increase in DA-HAIs (Grimm, 2021).

There were many differences between VAEs, CLABSIs, and CAUTIs. Significant increases were observed in VAEs in all the specified periods, though this was not the case with CAUTI and CLABSI which could be due to the focus shift on COVID-19 cases. As well as a change in patient populations as described before, as more people were being admitted for ventilator use versus any other procedure. Furthermore, reporting and surveillance could have changed during these periods as healthcare personnel were more focused on the COVID-19 cases (those on ventilators) which could have led to lapses in surveillance for other infections. In addition, variations in staffing levels and training of the staff could have impacted the infection rates. As stated previously, many healthcare personnel were placed in ICUs regardless of experience due to the influx of patients.

5.4 Strengths and Limitations

There are many strengths to consider in this study. The study obtained data from a span of 2018 to the first quarter of 2024, allowing there to be a baseline to be established to compare the pandemic and post-pandemic periods. This allowed there to be a large sample size, to evaluate how the infections changed during the specified periods. Furthermore, geographical location and bed size were included in the factors of interest to determine the differences in the facilities based on these factors which helps with target interventions. The data also spanned the three main invasive devices (central lines, indwelling catheters, and ventilators) to determine how these infections (CLABSI, CAUTI, and VAE) faired during the pandemic and whether there were differences between them. In addition, the study stratified the data by healthcare facility type. Other studies only examined ACHs and LTACs, while this study included IRFs and SCAs. This study was also to our knowledge to examine the DA-HAIs in the defined periods in the state of Nevada. In addition, since the data was oversaturated with zeros the statistical analysis of ZIP Regression was employed to account for the zeros, allowing for more meaningful results.

Although there were many strengths in the study, there were a few limitations. As previously mentioned, there were a lot of zeros in the data which indicated there were no infections. Any test that was run to exclude any outliers was null as it excluded the actual data points, thus excluding too much information, for that reason, the data remained with all data points. The study was population-level and not individual-level data thus certain information could have been lost such as age and comorbidities. Furthermore, the study utilized secondary data. Unit locations within healthcare facilities were not accounted for as there were convergence issues when the final analysis types were run. An organization effect was also not considered due to the addition of geographical location causing singularity issues thus only one of those variables was kept. Medical school affiliation was also not included in the analyses due to missing and contradictory information within the data sheets themselves for the same years and different unit locations.

Chapter 6: Conclusion

There were significant increases in VAEs, no changes in CAUTIs, and an increase in CLABSIs for ACHs across the three study periods. The pandemic resulted in many challenges for healthcare facilities. There were staff shortages, burnout, and fatigue of healthcare providers that led to the personnel requiring reminders and reeducation on basic infection prevention. In addition, there was possible decreased surveillance as resources and priorities went to COVID-19 patients. The continued increase in VAEs post-pandemic is concerning as the influx of COVID-19 patients has decreased since the declaration of the end of the pandemic.

Better guidelines should be in place to help decrease DA-HAIs to ensure they remain low through any future endeavors such as another pandemic. It is crucial for these facilities to closely monitor the processes and outcomes of the device usage both under normal circumstances and during abnormal ones. Disruptions from monitoring and reporting of the HAIs should be avoided at all times. In addition, providing regular feedback to healthcare workers would help in ensuring a safe environment for the patients. Furthermore, regular review of HAIs is crucial for healthcare facilities to detect any significant increases in infections, identify gaps, and implement interventions to effectively lower their incidence. Device utilization should also be examined to determine whether the use is necessary or when the earliest removal time is to decrease the risk of infection.

There is a need to further explore how the rates of DA-HAIs have changed because of the pandemic. Few studies have examined all three of the DA-HAIs, particularly VAEs. This study though did explore these infections, but they should be further explored beyond the pandemic to identify any holes left. Future studies should also stratify by medical affiliation type and add the unit location variable to determine any differences between those facilities and units. It is important to understand what and why these changes or lack of occurred. Being able to assess this would aid in understanding any lasting impact COVID-19 had on healthcare facilities to improve and sustain the infection control programs to endure any future pandemic.

Appendix A: CLABSI Literature Review Tables

Table 11: Central Line-Associated Bloodstream Infection (CLABSI) Literature Review in the Southeastern U.S. for Central Line Days, Rates, SIR, and SUR from January 2018 to March 2022

	Before the pandemic	During the pandemic	Increase or Decrease
Central line days	937	969	↑
	647	677	↑
Rates	0.6	0.9	↑
	0.56	0.86	↑
	0.68	1.16	↑
Standardized Utilization Ratio (SUR)	0.88	0.92	↑
Device Standardized Infection Ration (dSIR)	0.58	0.87	↑
Population SIR (pSIR)	0.51	0.81	↑

Table 12: Central Line-Associated Bloodstream Infection (CLABSI) dSIR in Months Where COVID-19 Admissions Were Less Than Five Percent or Greater Than 10 Percent Literature Review in 78 Hospitals From A Healthcare System from March 2020 to August 2020

COVID-19 admissions <5%	COVID-19 admission >10%
0.67	1.58

Table 13: Central Line-Associated Bloodstream Infection (CLABSI) Literature Review in the Southeastern U.S. for Hospital Types from January 2018 to March 2022

	Before the pandemic	During the pandemic	Percentage	Increase or Decrease
Acute Care VA Hospital	0.89	1.16		↑
Community Hospitals			48	↑
Large Hospitals	0.58	0.88		↑
Medium Hospitals	0.54	0.82		↑
Small Hospitals			82.1	↑

Appendix B: CAUTI and VAE Literature Review Tables

Table 14: Catheter-Associated Urinary Tract Infections (CAUTIs) Literature Review in the Southeastern and South U.S. for Catheter Days, Rates, SIR, and Hospital Types from January 2018 to March 2022

	Before the pandemic	During the pandemic	Increase or Decrease
Catheter days	798	817	↑
	675	686	↑
Rates	0.75	0.66	↓
	0.86	0.77	↓
Device Standardized Infection Ration (dSIR)	0.71	0.64	↓
Population SIR (pSIR)	0.58	0.57	↓
Acute Care VA Hospitals	0.93	1.02	↑
Non-ICU	0.85	0.66	↓

Table 15: Ventilator-Associated Events (VAEs) Literature Review in the Southeastern and South U.S. for Rates and Hospital Types from September 2016 to March 2022

	Before the pandemic	During the pandemic	Percentage	Increase or Decrease
Rates	3.10	1.82		↓
	6.1	10.9		↑
Acute Care VA Hospital	4.50	7.81		↑
Small Hospitals			48.7	↑
Medium Hospitals			104	↑
Community Hospitals			41.4	↑

Appendix C: IRB Exemption

UNLV

ORI-HS, Exempt Review
Exempt Notice

DATE: July 9, 2024

TO: Brian Labus
FROM: Office of Research Integrity - Human Subjects

PROTOCOL TITLE: UNLV-2024-283 The impact of the COVID-19 pandemic on device-associated healthcare-associated infections in Nevada
SUBMISSION TYPE: Initial

ACTION: Exempt
REVIEW DATE: July 9, 2024
REVIEW TYPE: EXEMPT
REVIEW CATEGORY: Category 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

(i) The identifiable private information or identifiable biospecimens are publicly available;

(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

This memorandum is notification that the protocol referenced above has been reviewed as indicated in Federal regulatory statutes 45 CFR 46 and deemed exempt under Category 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

(i) The identifiable private information or identifiable biospecimens are publicly available;

(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

PLEASE NOTE:
Upon final determination of exempt status, the research team is responsible for conducting the research as stated in the exempt application reviewed by the ORI – HS, which shall include using the most recently submitted Informed Consent/Assent and recruitment materials.

If your project involves paying research participants, it is recommended to contact HSComp@unlv.edu to ensure compliance with the Policy for Incentives for Human Research Subjects.

Any changes to the application may cause this study to require a different level of review. Should there be any change to the study, it will be necessary to submit a **Modification** request for review. No changes may be made to the existing study until modifications have been approved/acknowledged.

All **unanticipated problems** involving risk to subjects or others, and/or **serious and unexpected adverse events** must be reported promptly to this office.

Any **non-compliance** issues or **complaints** regarding this protocol must be reported promptly to this office.

Please remember that all approvals regarding this research must be sought prior to initiation of this study (e.g., IBC, COI, Export Control, OSP, Radiation Safety, Clinical Trials Office, etc.).

If you have questions, please contact the Office of Research Integrity - Human Subjects at IRB@unlv.edu or call 702-895-2794. Please include your study title and study ID in all correspondence.

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Curriculum Vitae

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Education

Master in Public Health, Epidemiology and Biostatistics **August 2024**
University of Nevada Las Vegas (UNLV)

Bachelor of Arts in Psychology, Minor in Neuroscience **August 2020**
University of Nevada Las Vegas (UNLV

Related Work Experience

Graduate Research Assistant **August 2023 – Present**
University of Nevada, Las Vegas

- Curating training materials on hospital-acquired infections for Nevada to be disseminated to healthcare facilities.
- Moderated a focus group session with Infection Preventionists in Nevada.
- Analyzing hospital-acquired infection and C. auris data to create a report to update Nevada surveillance.

Infection Prevention Intern **June 2023 – August 2023**
Sunrise Hospital, Las Vegas

- Observed hand hygiene from the staff and analyzed the data to help enforce infection prevention protocols.
- Audited C. auris and isolation precautions to ensure correct protocols were in place to prevent the spread of infections.
- Examined recent records to ensure infections were hospital-acquired or community-acquired.

Volunteer **June 2015-December 2018**
Sunrise Hospital and Sunrise Children's Hospital, Las Vegas

- Organized patient files to maximize office function efficiency.
- Created, updated, and coordinated appointments to ensure accurate data entry in the patient system.
- Located, retrieved, and faxed documents when necessary to ensure proper patient care.
- Sanitized toys, game systems, and the playroom between patients' use to decrease infection transference.
- Translated spoken Spanish between patients/patients' parents and caregivers ensuring understanding of both parties.

Membership in Professional Organizations

Biostatistical and Epidemiological Applied Methods for Student Society (BEAMSS) **September 2023 – Present**
Marketing and Communications Chair