Fall 2023

What Could Go Wrong? Patient and Hospital Characteristics Associated With Pediatric Quality of Inpatient Care and Pediatric Adverse Events

Michael H. Samawi

What Could Go Wrong? Patient and Hospital Characteristics Associated with Pediatric Quality of Inpatient Care and Pediatric Adverse Events.

By MICHAEL SAMAWI
(Under the Direction of Dr. Gulzar H. Shah)

ABSTRACT

This study aims to draw associations between pediatric adverse events (PAE) and hospital and patient characteristics in the inpatient hospital setting, utilizing the framework of pediatric quality indicators (PDIs) from the Agency for Healthcare Research and Quality (AHRQ) indicators. Three PDIs were identified and utilized for this purpose: NQI 03 Neonatal Blood Stream Infection (NBSI), PDI 09 Postoperative Respiratory Failure (PORF), and PDI 10 Postoperative Sepsis (POS). The data used for the study is based on an analysis of discharge data from the Healthcare Cost and Utilization Project (HCUP) Kids' Inpatient Databases (KID) for the year 2019. Through which, the study aims to answer research questions related to associations between hospital characteristics, and patient characteristics with specific PDIs. The methodology employed bivariate and multivariate logistic regression models to analyze patient-level encounters of the observed PAEs. The results showed that smaller, rural, and non-teaching hospitals had significantly lower odds of NQI 03, PDI 09, and PDI 10 compared to large hospitals. While individual factors such as gender, age, race, service lines, payment sources, and major operating room procedures played various roles of significance from PDI to the next, raising interest in continued study. The study expands upon the findings contextually and offers valuable insights into PAE in the inpatient hospital setting utilizing the PDIs framework while highlighting areas for developing evidence-based interventions and guidelines for clinicians and policymakers. The findings contribute to the growing body of knowledge on factors influencing NBSI, POS, and PORF.

INDEX WORDS: Neonatal blood stream infection, Postoperative respiratory failure, Postoperative sepsis, Quality improvement, Pediatric care, Pediatric adverse events

What Could Go Wrong? Patient and Hospital Characteristics Associated with Pediatric Quality of Inpatient Care and Pediatric Adverse Events.

MICHAEL SAMAWI

B.A., Georgia Southern University, GA, USA 2011

Master in Anthropology and Sociology of Development, The Graduate Institute of International and Development Studies, Geneva, CH, 2013

A Dissertation Submitted to the Graduate Faculty of Georgia Southern University in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PUBLIC HEALTH

JIANN PING HSU COLLEGE OF PUBLIC HEALTH

What Could Go Wrong? Patient and Hospital Characteristics Associated with Pediatric Quality of Inpatient Care and Pediatric Adverse Events.

by

Michael Samawi

Major Professor: Gulzar H. Shah

Committee: Linda Kimsey

Kristie C. Waterfield

Susan Hendrix

Electronic Version Approved:

December 2023

DEDICATION

Within this paper, woven with ceaseless years of pursuit, I pay tribute to my father, whose unwavering support has unveiled the depths of divine love. His steadfast care has graced both my life and academic voyages, instilling in me a resolute understanding of what it means to be a devoted person with passion, and to lead a life worth living.

ACKNOWLEDGMENTS

I would like to intently acknowledge all the great professors at the Jiann-Ping Hsu College of Public Health that have tirelessly assisted me on my academic journey and have challenged me consistently to achieve the best of my potential. I would like to acknowledge the efforts of Dr. Gulzar Shah, my advisor and dissertation supervisor for his generosity with his wealth of knowledge. Dr. Linda Kimsey, who has constantly inspired me with her military ethics. Dr. Kristie Waterfield for her stout attention to detail and Dr. Susan Hendrix from the Nursing department, for her inspiration in pursuing cross-disciplinary excellence.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

STATEMENT OF THE PROBLEM

Adverse events, often conflated with medical errors, cast a lingering shadow over healthcare systems globally. The famed publication of *To Err is Human: Building a Safer Health System* by the Institute of Medicine in 1999, set the stage for exploring and grasping the gravity and undesirable effects of adverse events (AE) (initially called medical errors) and gaps in patient safety. The first and most prominent stakeholder to respond to this warning trumpet has been the Agency for Healthcare Research and Quality (AHRQ) (AHRQ, 2022). This was not a secluded incident as the stage had been gradually set since the 19^{th} century for progression in quality-of-care surveillance, delimitation, and standardization (Garrouste-Orgeas et al., 2012). Yet in adhering to the concept of the faultiness of the healthcare *system* in its efforts to shield patients from these happenings, as opposed to a focus on the individual-human- provider who is prone to error, AHRQ has been able to develop tools that have aided the US health care system in preventing 1.3 million errors, saving thousands of lives, and an estimated $12 billion in wasted spending up till the year 2013 (AHRQ, 2022). Yet, defining the scope of AEs, and their impact on the healthcare system and the patient population remains a growing top priority despite the increased amount of research, the standardization of quality indicators, and the evolution within the fields of patient safety and quality improvement.

Adverse Events and Medical Errors

In 2016, a study by Johns Hopkins patient safety experts ascertained that the IOM report was outdated and, in its calculations, estimated that AEs surpassed the third leading cause of death in the U.S, accounting for 250,000 deaths per year based on extrapolating the medical death rate data from 2000 to 2008 to the number of hospitalized patients in 2013 (Makary &

Daniel, 2016). The study attributed these errors to systemic issues, from poorly coordinated care, to disintegrated insurance networks, the absence or underuse of safety nets, and unwarranted variation in physician practice, yet also attested to the importance of not laying blame on the human factor in errors (Makary & Daniel, 2016). Nevertheless, this study was not without critics and though it was propagated widely as fact, many issues were identified with the methodology, the math and the replicability of the data used on the entire U.S population (Jarry, 2021). This has left many on both sides of the aisle attempting to grasp the weight of AEs, their definition, and preventability. Nonetheless, according to many observations AEs were still understood, and gauged, to constitute the third leading cause of death in hospitals accounting for 210,000 to 400,000 patient deaths per year in U.S. hospitals (Falcone et al., 2022).

Pediatric Adverse Events

Over the past years, pediatric scholarship has not reached consensus on the prevalence of AEs in pediatric healthcare settings globally, including the United States. Agarwal et al. (2010) conducted a study in the Pediatric Intensive Care Unit (PICU), which revealed that 62% of patients experienced at least one pediatric adverse event (PAE) (Agarwal et al. 2010). Davenport et al. (2017) found an AE frequency of 26% among hospitalized pediatric patients. Various other studies have reported PAE rates between 10% and 62% depending on the patient population and setting in pediatric healthcare (Sharek et al., 2010). These findings highlight the significant problem that AEs pose for pediatric patients (Davenport et al., 2017). In the past two decades, PAEs have consistently been reported to cause substantial morbidity and mortality. PAE rates leading to harm remain significantly high, with neonatal intensive care units (NICUs) having an estimated rate of 74 harms per 100 patients, PICUs at 203 per 100 patients, and teaching children's hospitals at 40 harms per 100 admissions (Stockwell et al., 2018). The rates of PAEs due to medical care have not decreased over time, indicating the need for ongoing efforts to reduce harm through contextually informed and comprehensive strategies (Stockwell et al., 2018). Moreover, across the board, it has been observed that the consequences of PAEs are severe, leading to increased morbidity, mortality, and healthcare costs (Agarwal-Harding et al., 2019). Furthermore, certain patient populations, such as surgical patients and those requiring intubation, are at a higher risk of experiencing PAEs (Miller MR et al., 2011). This underscores the need for a multifaceted approach to prevent PAEs, including adequate staffing levels, standardized tools for identifying PAEs, and reporting systems (Miller MR et al., 2011).

Definitions

The definitions of AEs, and medical errors, have undergone refinement over time. The Institute of Medicine (IOM) defined an AE as "an injury resulting from medical intervention" in their report "To Err is Human" (IOM, 2000). The World Health Organization (WHO) introduced a broader definition of patient safety incidents in 2005, including "errors and mistakes" and "system failures" that result in harm to the patient (WHO, 2005). The WHO further defined AEs as “untoward occurrences that may happen during treatment, not necessarily caused by the treatment itself, including incidents after medical procedures, exposure to environmental contaminants, or when discontinuing medication” (WHO, 2002). The National Quality Forum (NQF) endorsed earlier a more grounded definition, describing AEs as "harm resulting from medical care" (NQF, 2006). Scholars have also proposed separating preventable AEs from non-preventable AEs and distinguishing between minor and major AEs to better capture different types of harm (Kohn et al., 2000). It was concluded early on that establishing standardized definitions across healthcare settings is crucial to improve comparability across studies (Kohn et al., 2000). As the definition evolved more acknowledgment of the role of processes of care and the distinction between avoidable errors and AEs resulting from disease progression began to crystalize (Gober & Bohnen, 2005; Garrouste-Orgeas et al., 2012; Falcone et al., 2022). This alongside the role of patients and families in identifying and reporting AEs, as their perspectives can provide valuable insights for healthcare quality improvement (WHO, 2020). By this, harm has expanded to be defined as "the physical or psychological injury or damage to health" and can be influenced by factors beyond medical care, such as the “social determinants of health”; emphasizing the role of socially embedded contexts in the development and progression of AEs (WHO, 2020).

In terms of research methodology, preventable AEs were found to cost $1 billion in comparison to the $17 billion estimated cost of AEs on the general population by the IOM (Harding, 2004; IOM, 2000). Despite limitations in estimating AEs using indicators and administrative data, these studies highlighted the importance of clearly defining medical errors and AEs and implementing a comprehensive definition for operational purposes (Harding, 2004). The unique characteristics of PAEs were also emphasized, as they had been comparatively overlooked in broader medical error prevention research and quality improvement efforts (Slonim et al., 2003). Studies have proposed new approaches for identifying AEs beyond traditional incident reporting systems. Trigger tools, for example, utilize structured data queries in electronic health records (HER) to identify potential AEs based on patterns (Classen et al., 2011). These are deemed as important localized examinations of the PAEs but lack a widespread understanding of PAE trends.

Overall, pediatric medical error scholarship has consistently demonstrated the prevalence and impact of AEs in pediatric healthcare settings globally. The definitions of AEs and medical errors have evolved, emphasizing the need for standardized approaches, and capturing different types of harm. Efforts to improve patient safety and prevent AEs require a multifaceted approach, including adequate staffing, standardized tools, and reporting systems. Patient and family perspectives, alongside advancements in research methodology, are increasingly recognized as crucial factors in identifying and addressing AEs.

Pediatric Quality Indicators

As part of AHRQs role within the Department of Health and Human Services, it has developed certain QIs to measure healthcare quality in a standardized fashion (AHRQ, 2020). These Qis constitute a set of Pediatric Quality Indicators (PDIs) that provides measurements for potentially preventable complications and iatrogenic events for pediatric patients as well as preventable hospitalization for children (AHRQ, 2020)

In 2006, AHRQ, in partnership with their evidence-based centers, created PDIs to distinguish them from PQIs, the patient quality indicators, as part of their active response to the Healthcare Cost and Utilization Project (HCUP) request to create effective measures for multilevel/sector actors to engage in quality improvement and safety (AHRQ, 2020). These measures have been refined over the years to include risk adjustments, reference populations and ICD-10 coding (AHRQ, 2020). PDIs, as the other Quality Indicators (QI)s created, have been designed to measure quality and utilization at two different levels, area, and hospital-level indicators (AHRQ, 2020). Area-level PDIs have been designed for purposes of population health and prevention quality measurements (AHRQ, 2020). Whereas, with regards to Hospital-level indicators, the following is defined by AHRQ for their application:

> "Hospital-level indicators capture potentially preventable complications or adverse events following a medical condition or procedure or mortality following a medical condition or surgical procedure in which evidence suggests that high mortality may be associated with

> deficiencies in care. For example, hospital-level indicators may answer the question: Did the patient experience an adverse quality-related event while in the hospital? As a practical matter, the default unit of analysis for hospital-level AHRQ QIs is the hospital." (p.5).

With this classification given by AHRQ, the above-mentioned definitions of AEs can be successfully measured through the utilization of hospital-level PDIs as opposed to the area-level indicators. This study relies on the above classification for its understanding of PAE and the quality improvement measure that have progressed over the decades to investigate, measure, and mitigate them.

PURPOSE OF THE STUDY

This research aims to assess the gravity of PAEs in the inpatient hospital setting, utilizing the framework of pediatric quality indicators (PDIs). The study also seeks to analyze the association of hospital and patient characteristics with PDIs at the patient level of analysis.

Given the severity of AEs in pediatric populations, it is imperative to establish a clear and recent overview of the risk factors associated with these events. Three PDIs have been identified and utilized for the purpose of this study, NQI 03 Neonatal Blood Stream Infection, PDI 09 Postoperative Respiratory Failure Rate, and PDI 10 Postoperative Sepsis Rate. These indicators have been chosen for their higher prevalence as an observed rate per 100,000 discharges according to benchmark data tables prepared by AHRQ (Table 1.) (AHRQ, 2022). These tables present nationwide comparative rates for the 2022 version of AHRQ's QI PDI software (AHRQ, 2022). The rates indicated in the table are as follows: (20.23) for NQI 03, (26.48) for PDI 09, and (8.80) for PDI 10 (AHRQ, 2022). Furthermore, the data is based on an analysis of discharge data from the 2019 AHRQ's HCUP Kids' Inpatient Databases (KID) which is part of HCUP's comprehensive healthcare database, containing information on inpatient discharges since 1988, including patient demographics, diagnoses, procedures, length of stay, and more (HCUP,2022). In 2019, HCUP covered over 97% of all annual discharges in the US (HCUP, 2022).

Table 1. PDI for Overall Population: Hospital-Level Indicators taken from the 2019 State Inpatient Database (SID) (AHRQ, 2022)

PDI Benchmark Tables

Table 1. Pediatric Quality Indicators (PDI) for Overall Population: Hospital-Level Indicators

INDICATOR	LABEL	NUMERATOR	DENOMINATOR	OBSERVED RATE PER 1,000 DISCHARGES
NQI 03	Neonatal Blood Stream Infection Rate	1,518	75,049	20.23
PDI 01	Accidental Puncture or Laceration Rate	881	2,852,588	0.31
PDI 05	Iatrogenic Pneumothorax Rate	141	2,588,391	0.05
PDI 08	Perioperative Hemorrhage or Hematoma Rate	280	99,663	2.81
PDI 09	Postoperative Respiratory Failure Rate	2,287	86,367	26.48
PDI 10	Postoperative Sepsis Rate	1,574	178,799	8.80
PDI 12	Central Venous Catheter-Related Blood Stream Infection Rate	981	2,300,480	0.43
PSI 17	Birth Trauma Rate – Injury to Neonate	15,053	3,268,942	4.60

The study aims to address this knowledge gap by utilizing the PDIs with the highest prevalence as an overview of overall quality and pediatric patient safety, and answering the following research questions:

Research Questions:

A) Are hospital characteristics associated with three most prevalent PDIs?

B) Are patient characteristics associated with three most prevalent PDIs?

Hypothesis:

H1A. Hospital region is significantly associated with NQI 03 when controlling for other risk factors.

H2A. Teaching/nonteaching status of the hospital is significantly associated with NQI 03 when controlling for other risk factors.

H3A. Rurality of the hospital is significantly associated with NQI 03 when controlling for other risk factors.

H4A. Control ownership of the hospital is significantly associated with NQI 03 when controlling for other risk factors.

H5A. Hospital bed size is significantly associated with NQI 03 when controlling for other risk factors.

H1B. Gender is significantly associated with NQI 03 when controlling for other risk factors.

H2B. Payor status is significantly associated with NQI 03 when controlling for other risk factors.

H3B. Race is significantly associated with NQI 03 when controlling for other risk factors.

H4B. Previous major operation status is significantly associated with NQI 03 when controlling for other risk factors.

H5B. Service line is significantly associated with NQI 03 when controlling for other risk factors.

H6B. Age is significantly associated with NQI 03 when controlling for other risk factors.

H1.A.2. Hospital region is significantly associated with PDI 09 when controlling for other risk factors.

H2.A.2. Teaching/nonteaching status of the hospital is significantly associated with PDI 09 when controlling for other risk factors.

H3A.2. Rurality of the hospital is significantly associated with PDI 09 when controlling for other risk factors.

H4A.2. Control ownership of the hospital is significantly associated with PDI 09 when controlling for other risk factors.

H5A.2. Hospital bed size is significantly associated with PDI 09 when controlling for other risk factors.

H1B.2. Gender is significantly associated with PDI 09 when controlling for other risk factors.

H2B.2. Payor status is significantly associated with PDI 09 when controlling for other risk factors.

H3B.2. Race is significantly associated with PDI 09 when controlling for other risk factors.

H4B.2. Previous major operation status is significantly associated with PDI 09 when controlling for other risk factors.

H5B.2. Service line is significantly associated with PDI 09 when controlling for other risk factors.

H6B.2. Age is significantly associated with PDI 09 when controlling for other risk factors.

H1A.3. Hospital region is significantly associated with PDI1 0 when controlling for other risk factors.

H2A.3. Teaching/nonteaching status of the hospital is significantly associated with PDI 10 when controlling for other risk factors.

H3A.3. Rurality of the hospital is significantly associated with PDI 10 when controlling for other risk factors.

H4A.3. Control ownership of the hospital is significantly associated with PDI 10 when controlling for other risk factors.

H5A.3. Hospital bed size is significantly associated with PDI 10 when controlling for other risk factors.

H1B.3. Gender is significantly associated with PDI 10 when controlling for other risk factors.

H2B.3. Payor status is significantly associated with PDI 10 when controlling for other risk factors.

H3B.3. Race is significantly associated with PDI 10 when controlling for other risk factors.

H4B.3. Previous major operation status is significantly associated with PDI 10 when controlling for other risk factors.

H5B.3. Service line is significantly associated with PDI 10 when controlling for other risk factors.

H6B.3. Age is significantly associated with PDI 10 when controlling for other risk factors.

SIGNIFICANCE

The COVID-2019 pandemic has underscored systemic issues within the healthcare system, leading to a decline in trust. A 2021 survey conducted by Nonpartisan and Objective Research Organization NORC at the University of Chicago revealed a decrease in trust in healthcare systems by 30% among physicians and 32% among the public (NORC, 2021). The survey also found that only 64% of the public expressed trust in the healthcare system in its entirety (NORC, 2021). Interestingly, a third of physicians reported a lack of trust in healthcare leadership or executives, despite having increased trust in their fellow physicians and nurses (NORC, 2021).

The reporting of AEs remains a significant challenge in patient safety and quality improvement literature. A recent integrative review identified a lack of reporting of AEs in acute care hospitals. This underreporting was attributed to various factors, including fear of blame and retaliation, inadequate feedback, and hierarchal power structures within the healthcare system (Falcone et al., 2022). The study emphasized the cultural, environmental, and communicative aspects of healthcare environments that contribute to underreporting.

Disparities in AE reporting have also been observed in pediatric populations. A study conducted at an academic children's hospital compared voluntary event reporting (VER) with trigger tools, such as the Global Assessment of Pediatric Patient Safety (GAPPS). Trigger tools have been shown to capture over 10 times the number of adverse events compared to VER. The use of trigger tools revealed significantly higher rates of AEs, particularly among children with limited English proficiency. The underuse of trigger tools and the reliance on VER can result in systematic underreporting of AEs, which disproportionately affects vulnerable populations (Halvorson et al., 2022).

Given the growing public awareness of patient safety, the unique nature of pediatric quality improvement and patient safety, and the decline in trust in healthcare systems, this study is of utmost significance. By utilizing the largest nationwide database available, this study aims to identify associated characteristics of PAEs and develop prediction-based methodologies for prevention. The findings of this study will contribute to quality improvement efforts and inform policymakers, educators, and healthcare management systems. Ultimately, this research can facilitate evidence-based recommendations for quality control and educational curricula, while also paving the way for future studies focused on PAEs.

DELIMITATION

This study utilizes the HCUP KID’s database for the year 2019. These years have been selected for being the most recent available datasets that utilize (ICD-10) coding system, the significance of which will continue to be expanded upon throughout the study. Those years are also useful for analysis because they precede the COVID-19 pandemic and the particularities of pressure imposed onto the healthcare system due to the pandemic, which would require a different framework of study. Furthermore, this study utilizes AHRQ hospital-level PDIs with the aim to examine previous claims of their utility and comprehensibility in gauging patient harm, safety, and quality improvement measures. At the time of this study, no comprehensive application of AHRQ PDIs have been found to be applied to the KID datasets for 2019.

DEFINITION OF TERMS

Pediatric Adverse Events (PAE): Pediatric adverse events refer to any harmful or unintended medical events that occur in children who have received medical treatment or intervention. These events can include physical injuries, medical errors, adverse reactions to medications, and infections acquired during treatment. The severity of pediatric adverse events can range from mild to life-threatening and can have both short-term and long-term consequences for the child's health.

PDI: Pediatric Quality Indicators are measures used to assess the quality of healthcare delivered to children. PDIs use hospital discharge data to identify potentially preventable complications and adverse events and are used by healthcare organizations and policymakers to evaluate the quality of care, identify areas for improvement, and monitor changes in outcomes over time.

PQI: Patient Quality Indicators are measures used to assess the quality of care provided to patients in various settings, including hospitals, clinics, and long-term care facilities. PQIs use administrative data, such as discharge records or claims data, to identify and measure potentially preventable complications or adverse events.

QI: Quality Indicators are measures or tools used to assess, evaluate, and prioritize aspects of quality or performance in healthcare organizations. QIs may focus on different areas, such as patient safety, clinical effectiveness, patient experience, or cost-effectiveness.

AHRQ: Agency for Healthcare Research and Quality

HCUP: Healthcare Cost & Utilization Project

KID: Kid’s Inpatient Database

ICD-9: International Classification of Diseases, 9th Revision

ICD-10: International Classification of Diseases, 10th Revision

NBSI: Neonatal Blood Stream Infection refers to the presence of bacteria in the blood of a newborn baby, often contracted during or shortly after birth. NBSI is considered a serious condition that can lead to sepsis, organ failure, and even death if not promptly diagnosed and treated.

NICU: Neonatal Intensive Care Unit

PORF: Postoperative respiratory failure refers to a life-threatening complication that can occur after surgery. PORF is characterized by a failure of the respiratory system to maintain adequate oxygenation or ventilation, leading to hypoxemia or hypercarbia. It can be caused by numerous factors, such as anesthesia-induced lung injury, pneumonia, or acute respiratory distress syndrome (ARDS). PORF can lead to prolonged hospitalization, re-intubation, and higher mortality risk.

POS: Postoperative sepsis is a potentially life-threatening condition that can occur after a surgical procedure when a bacterial or fungal infection spreads to the bloodstream. It is characterized by a systemic inflammatory response from the body's immune system that can lead to organ dysfunction and failure.

CLABSI: Central line-associated bloodstream infections result in thousands of deaths each year and billions of dollars in added costs to the U.S. healthcare system, yet these infections are preventable according to the CDC.

CHAPTER 2: LITERATURE REVIEW

Adverse Events in Pediatric Care Background

In recent years, patient safety and quality improvement have emerged as key priorities in healthcare systems. However, pediatric safety issues in hospital care have remained pervasive and have not shown any signs of decline (Mueller et al., 2019). Errors have been reported to affect as many as one-third of hospitalized children, contributing to adverse patient outcomes due to the unique contexts in which pediatric care is provided (Mueller et al., 2019). Pediatric patients are particularly vulnerable to medication errors due to their developmental stage, dependence, and distinct disease pathologies. Unfortunately, EHR and other systemized processes are often designed with the adult patient in mind, presenting additional challenges in pediatric care (Mueller et al., 2019).

Three main factors have been identified as contributing to pediatric safety problems: physical characteristics, developmental issues (such as physical or mental age), and legal status as a minor (Mueller et al., 2019). Moreover, pediatric care in Emergency Medicine and Emergency Departments (ED) faces increased risks of medication errors due to the chaotic and unpredictable nature of these settings, with multiple patients, diverse tasks, and varying acuity levels (Mangus & Mahajan, 2019). Time sensitivity, patient prioritization, sleep deprivation, and limited information further contribute to the heightened risks of medical errors and patient harm in pediatric EDs (Mangus & Mahajan, 2019). Pediatric patients also pose unique challenges, including the need for effective communication of symptoms, appropriately sized equipment, accurate weight-based dosing, and consideration of age-specific manifestations of disease in vital signs and physiology (Mangus & Mahajan, 2019). Within the ED, studies have explored medication dosing and administration, laboratory evaluation and communication, and diagnosis errors, which have been identified as the most prevalent yet understudied form of medical errors in this setting (Mangus & Mahajan, 2019).

Early studies, such as the 2003 study by Slonim et al., provided a comprehensive analysis of hospital-reported medical errors in children, using the largest and most complete inpatient data available at the time (Slonim et al., 2003). This study analyzed data from 1988, 1991, 1994, and 1997, categorizing medical errors into five groups based on the HCUP ICD-9 database, including drug errors and different types of complications (Slonim et al., 2003). While patient characteristics showed no difference in the rate of medical errors when stratified by gender, race, payer status, or income, a statistically significant association was found with being male (Slonim et al., 2003). This trend has been observed in several other studies examining similar characteristics of medical errors (Feyissa et al., 2020; Tansuwannarat et al., 2022). However, it is important to consider the relevance and applicability of these findings in establishing a baseline understanding of medical errors or adverse events in current pediatric patients, given the differences in available data.

The implementation of the ICD-10 classification in 2015 significantly impacted medical reporting and research, creating a knowledge gap in the understanding of medical procedures and errors beyond the constraints of outdated ICD-9 parameters (HCUP, 2022). The switch to the ICD-10 coding system resulted in an exponential increase in data entries, reflecting a wider range of diagnoses and time phases of experience (HCUP, 2022). It is also worth noting that the Slonim et al. (2003) study was completed before the widespread use of the AHRQ Patient Safety Indicators (PDI) in 2006, and it did not specify which HCUP database was utilized, as there are multiple nationwide databases, including KID, specific to pediatric care (HCUP, 2022). However, a study by Rhee et al. (2012) demonstrated the effectiveness of PDI in measuring patient safety outcomes in pediatric surgical patients when using the HCUP KID and Nationwide Inpatient Sample (NIS) databases from 1997 to 2006. This study found associations between PDIs, patient characteristics, and hospital factors, highlighting increased risks of mortality, length of stay, and total hospital charges (Rhee et al., 2012).

A recent study by Milliren et al. (2022) focused on the application of safety indicators from AHRQ and the Centers for Medicare and Medicaid Services to data from discharged patients in 45 freestanding pediatric hospitals between 2016 and 2019. This study aimed to challenge the notion of a single "safest" hospital and demonstrate the limitations of composite indicators in capturing the complexity of patient safety. The findings revealed that no hospital consistently performed well across all indicators, emphasizing the need to consider multiple measures and avoid oversimplification (Milliren et al., 2022).

Several studies have used pediatric-specific PDIs to assess the quality of care, however, they have not been without concerns as there are those with apprehensions as to their usefulness in comparing hospital quality due to the low occurrence of each event (Smith et al., 2012). Some studies suggested creating a composite measure by combining multiple AEs into one measure, by this, overcoming the issue of weak numbers associated with individual PDIs (Smith et al., 2012). AHRQ itself has developed a composite version of the PDIs to detect differences in safety performance across providers.

In the earlier study by Smith et al., (2012) aimed at gauging the weight of Medicaid and resource-poor dependent hospitals on PAEs, a composite indicator was created by selecting eight out of the thirteen provider-level PDIs (Smith et al., 2012). The composite indicator was found to capture the frequency of AEs better than each individual PDI, with an increase in frequency about fivefold compared to a singular PDI (Smith et al., 2012). Moreover, the main findings from the analysis indicated that within hospitals with high pediatric-discharge rates, children in hospitals with higher Medicaid discharge rates were more likely to experience AEs compared to those in hospitals with lower Medicaid discharge rates (Smith et al., 2012). Other statistically significant factors related to AEs included severity of illness, age, income level, insurance status (Medicaid), case mix (pediatric average APR-DRG severity index), average number of procedure codes, hospital bed size (medium), teaching status, urban location, ownership type (for-profit), and state-level Medicaid reimbursement index (Smith et al., 2012).

Though this study recognizes the benefits of such composites, it nonetheless, adheres to the importance of particular characteristics involved with each of the identified PDIs in order to assess researchers and care providers to consider individualized and tailored QI measures.

Further, given the expansion and classification of PAE, the transition to the ICD-10 coding system with increased data points, and the increased utilization of quality indicators in measuring and improving quality and safety, there is a growing demand to understand the unique characteristics of PAE and prioritize evidence-based harm reduction measures. This study aims to deepen our understanding of PAE by analyzing core PDIs using the 2019 KID from HCUP. Through this comprehensive analysis, the utility of these indicators in identifying iatrogenic patient harm will be assessed. The following sections explore the three PDIs utilized in this study, providing valuable insights for policymakers, educators, and healthcare professionals seeking to enhance pediatric patient safety.

NQI 03 NEONATAL BLOOD STREAM INFECTION

Neonatal blood stream infection (NBSI) is a serious complication of neonatal care that can lead to morbidity and mortality. Several studies have examined the incidence of NBSI and its associated risk factors. A study conducted by Stoll et al. (2011) found that the incidence of NBSI decreased from 2005 to 2009, yet identified several risk factors, including low birth weight, prolonged rupture of membranes, and mechanical ventilation. Other studies reiterated the high risk of low-birth-weight infants for NBSI and further identified that coagulase-negative staphylococci (CoNS) as the most common causative organism (Stoll et al., 2020).

A study from 2005 to 2014 that assessed the incidence and impact of Group B Streptococcus (GBS) and Escherichia coli infections in early-onset neonatal sepsis (EOS) in multiple states found that out of 1484 cases, GBS was the most common cause (532 cases), followed by Escherichia coli (E.coli) (368 cases) (Stephanie et al., 2016). That study observed that the overall incidence rates for sepsis remained stable, with a slight decrease in GBS incidence but no significant change in E. coli incidence (Stephanie et al., 2016). Incidence rates for both pathogens were higher in infants weighing less than 1500 grams, showing similar odds of death (Stephanie et al., 2016). However, among infants weighing at least 1500 grams, E. coli cases had greater odds of death. The study concludes that efforts to prevent GBS infections did not increase E. coli infections, but further interventions are needed to address the mortality concerns of E. coli sepsis despite stable incidence rates (Stephanie et al., 2016).

More recent research, conducted by the Eunice Kennedy Shriver National Institute of Child Health and Human Development Neonatal Research Network from 2015 to 2017, focused on a cohort of infants born with a gestational age of at least 22 weeks and a birth weight greater than 400g. The study included data from 18 research centers (Stoll et al., 2020). The study found an overall incidence rate of early-onset sepsis (EOS) of 1.08 cases per 1000 live births. It also revealed higher rates of EOS among preterm infants compared to term infants. The most common pathogens identified were E.coli and GBS, with E.coli more frequently observed in preterm infants and GBS more frequently observed in term infants. The study also highlighted missed opportunities for GBS prevention due to incomplete screening or prophylaxis administration. Empirical antibiotic treatment primarily consisted of ampicillin and gentamicin. The study noted an increased resistance to ampicillin among E.coli isolates. Additionally, the study found a high survival rate for infected infants, but a higher mortality rate among preterm infants compared to term infants (Stoll et al., 2020). The study also compared rates with an earlier surveillance study conducted by NRN from 2006-2009, finding an increase in E.coli infection rate among very low-birth-weight (VLBW) infants in the current study compared to the previous one (Stoll et al., 2020). Overall, this study highlighted the ongoing challenges posed by EOS and emphasized the need for continued surveillance and novel prevention strategies (Stoll et al., 2020).

In the face of increasing antibiotic resistance, the importance of infection control measures and judicious use of antibiotics in the prevention and management of NBSI is brought to the forefront. In a comprehensive review into neonatal multidrug-resistant gram-negative (MDR-GN) infections, highlighting their increasing prevalence in neonatal settings (Flannery et al., 2022). The article identified ESBL-producing Enterobacterales and carbapenem-resistant Enterobacterales (CRE) as the most urgent MDR-GN threats as mechanisms of antibiotic resistance (Flannery et al., 2022. The study explored the risk factors for MDR-GN colonization and infection, such as prematurity, prolonged hospitalization, and the use of invasive devices (Flannery et al., 2022. The study emphasized the importance of appropriate antibiotic therapy and treatment options for MDR-GN organisms and underlined the critical role of infection control measures in preventing the horizontal transmission of MDR-GN pathogens in neonatal intensive care units (NICUs) (Flannery et al., 2022). These findings, and the many others, highlight the urgency needed in research and interventions to combat antibiotic resistance in this vulnerable population. This current study feeds into the research needed with regards to the particular ages associated with significantly burdening socioeconomic and sociodemographic factors.

Moreover, this study expands upon previous research in healthcare practice that have investigated the effects of central line "bundles" on central line-associated bloodstream infections and catheter-related complications (CLABSI) in NICUs (Bierlaire et al., 2021). In this study, a QI prospective, before-after design was utilized (Bierlaire et al., 2021). During the intervention period, changes were made to materials used and new bundles related to various aspects of central lines care were implemented (Bierlaire et al., 2021). The CLABSI rates were measured pre- and post-intervention period, where the implementation of the new bundles and changes in materials resulted in a significantly decreased rate of CLABSI as well as decreased catheter-related complications (Bierlaire et al., 2021). The analysis emphasized that the implementation of evidence-based bundles is crucial for reducing CLABSI rates in NICUs (Bierlaire et al., 2021).

The findings of this research will aid in understanding how to apply such bundles and target them by offering a a nation-wide perspective that allows for personalization, further aiding in the predictability of the observable factors contributing to higher rates of incidence.

PDI 09 POSTOPERATIVE RESPIATORY FAILURE

Postoperative respiratory failure (PORF) defined by impaired blood gas exchange appearing after surgery, is a common complication following surgery leading to longer hospital stays and increased mortality (Canet et al., 2014). Studies have identified predictors of PORF risk, including the type of surgery, comorbidities, mechanical ventilation, and lung injury (Canet et al., 2014). Risk-scoring systems are being developed and validated to aid in prediction, while managing intraoperative ventilation, fluid administration, reducing surgical aggression, and preventing infection and pain have been recommended strategies (Canet et al., 2014). However, more high-quality trials are needed to explore preventive measures for both high-risk and general patient populations.

In a retrospective case-control study aimed to identify risk factors for pediatric PORF and develop a predictive model using the US National Inpatient Sample (NIS) from 2012 to 2014 data (Gupta et al., 2021). The study selected significant predictors including demographic variables, type of surgical procedure, a modified pediatric comorbidity score, presence of substance abuse diagnosis, and presence/absence of kyphoscoliosis (Gupta et al., 2021). The primary outcome measure was the pediatric quality indicator (PDI 09). The study utilized the NIS data sets from 2012, 2013, and 2014, including patients aged 17 and younger (Gupta et al., 2021). The study found that the incidence of pediatric PORF varied from 1.31% in 2012 to 1.41% in 2014 within the NIS data sets (Gupta et al., 2021). Significant risk factors for the development of PORF were identified, including abdominal surgery showed with an odds ratio (OR) of 1.92 in the 2012 data set and 1.79 in the 2013 data set (Gupta et al., 2021). Similarly, spine surgery had an OR of 7.10 in the 2012 data set and 6.41 in the 2013 data set (Gupta et al., 2021). An elevated pediatric comorbidity score (score of 3 or greater) was associated with an OR of 32.58 in the 2012 data set and 22.74 in the 2013 data set (Gupta et al., 2021). With a predictive model incorporating the identified risk factors, the study suggested that pediatric patients undergoing noncardiac surgery, specifically those undergoing abdominal or spine surgery, are at higher risk for PORF (Gupta et al., 2021). Additionally, increased pediatric comorbidity scores were strongly associated with an elevated risk of PORF (Gupta et al., 2021).

Furthermore, a study examining the predictors of unplanned endotracheal tube intubation (UPI) in children undergoing noncardiac surgery, revealed that age under one year and longer operative time was a significant predictor (Cheon et al., 2016). The researchers analyzed data from the American College of Surgeons National Surgical Quality Improvement Program Pediatric database, which included 87,920 patients (Cheon et al., 2016). They divided the data into derivation and validation cohorts and used logistic regression models to identify independent predictors of UPI within 72 hours after surgery (Cheon et al., 2016). The final model included factors such as operation time, severe cardiac risk factors, American Society of Anesthesiologists physical status classification greater than or equal to 2, tumor involving the central nervous system, developmental delay/impaired cognitive function, past or current malignancy, and neonate status (Cheon et al., 2016). The researchers found that having an early UPI was associated with an increased risk of unadjusted all-cause 30-day mortality (Cheon et al., 2016). Neonates showed a higher susceptibility to respiratory morbidity due to physiological factors such as diaphragmatic fatigue, increased closing volumes, and diminished hypercapnic ventilatory drive (Cheon et al., 2016). Prolonged anesthesia during surgery can also contribute to complications like atelectasis, airway edema, fluid overload, and venous thrombosis (Cheon et al., 2016). The cumulative effect of multiple risk factors increased the incidence of UPI. UPI, in turn, was an independent predictor of increased mortality (Cheon et al., 2016). Preventive measures suggested could include chest physiotherapy, noninvasive ventilation, helium-oxygen therapy, and potentially exploring strategies like low intraoperative tidal volume. This research did not show patient characteristics other than age as predictors (Cheon et al., 2016).

By associating factors related to age and other factors, this study paves the way to directing clinicians in identifying high-risk patients, anticipate PORF-related incidents, and implement interventions to improve outcomes.

PDI 10 POSTOPERATIVE SEPSIS

Pediatric postoperative sepsis can be defined as a systemic inflammatory response syndrome (SIRS) following surgery in pediatric patients, which is complicated by an identified or suspected infection (Singer et al., 2016). According to the Surviving Sepsis Campaign Guidelines, sepsis can be defined as life-threatening organ dysfunction caused by a dysregulated host response to infection (Singer et al., 2016). In the context of pediatric postoperative care, sepsis may occur due to infection of the surgical site, urinary tract, or respiratory system, among others with early identification and treatment being critical in preventing further morbidity and mortality in young patients (Singer et al., 2016).

In a study that compares the risk factors and characteristics of pediatric patients with severe sepsis who have undergone surgery versus those with medical sepsis, examined 556 patients in total with the aim of identifying differences in patient characteristics, sources of infection, bacterial pathogens, and outcomes between the two groups (Thakkar et al., 2019). The results showed that children in the postsurgical group are more likely to be younger and have multiple comorbidities related to gastrointestinal and/or cardiovascular systems (Thakkar et al., 2019). They were also more likely to have abdominal sources of infection and be infected with gram-negative bacteria, though fungal infection were found to occur in similar proportions in both groups (Thakkar et al., 2019). The study also found that mortality rates were similar between the two groups but identified different risk factors for death (Thakkar et al., 2019). In postsurgical sepsis, risk factors included cardiovascular and respiratory comorbidities and higher age, in comparison to the risk factors of medical sepsis which included hospital-acquired infections, higher severity scores at ICU admission, presence of malignant comorbidities, and coming from a resource-limited region (Thakkar et al., 2019). The study also found that postsurgical patients had greater resource utilization and longer lengths of stay compared to medical patients (Thakkar et al., 2019). And the presence of multiple organ dysfunction syndrome (MODS) was a common risk factor for death in both groups, calling for further research into developing specific care bundles for surgical patients with sepsis as well as the need for improved recognition and management of sepsis in postoperative patients (Thakkar et al., 2019).

Regarding such bundles, a study that examined the incidence of major infections following pediatric cardiac surgery before and after the implementation of CLABSI bundle, compared the rates of surgical site infection (SSI), bloodstream infection (BSI), and ventilator-associated pneumonia (VAP) before and after the implementation of the CLABSI bundle (Vachirapuranon et al., 2022). The study also identified risk factors for major infections by conducting a retrospective analysis of 548 children who underwent cardiac surgery over a two-year period (Vachirapuranon et al., 2022). The results showed that the implementation of the CLABSI bundle led to a significant reduction in BSI, while VAP rates tended to decrease but not significantly and SSI rates remained unchanged (Vachirapuranon et al., 2022). The study identified age at surgery, postoperative ventilator usage, central line usage, and pre-CLABSI bundle period as independent risk factors for major infections (Vachirapuranon et al., 2022). The authors emphasize the importance of sustained application of prevention bundles and ongoing monitoring through compliance audits to reduce major infections in pediatric cardiac surgery patients (Vachirapuranon et al., 2022).

In summary, this comprehensive review highlights the ongoing challenges and risks faced by pediatric patients in healthcare settings. Factors such as developmental stage, dependence, and distinct disease pathologies contribute to their unique vulnerabilities. The chaotic nature of emergency medicine further compounds the risks. The transition to the ICD-10 coding system and increased use of quality indicators have expanded our understanding of patient safety in pediatrics but have also introduced new challenges in data analysis.

The studies reviewed focus on specific issues encountered by pediatric patients, including NBSI, PORF, and POS. These studies identify risk factors, outcomes, and potential preventive measures, emphasizing the need for personalized care and interventions.

Overall, this research underscores the importance of continuous efforts to improve the quality and safety of pediatric care by tailoring interventions to the specific characteristics and needs of pediatric patients. It provides valuable insights for policymakers, educators, and healthcare professionals aiming to enhance pediatric patient safety. Further research is crucial for developing evidence-based harm reduction strategies and improving the quality of care for pediatric patients.

CHAPTER 3: METHODOLOGY

STUDY DESIGN

This study employs a population-based retrospective cohort design. This type of observational study involves identifying a population that shares a common characteristic or exposure and following them over time to assess the development of specific outcomes. This study design is particularly useful for investigating rare outcomes or exposures that would be difficult to study in a prospective design. It also allows for the examination of long-term outcomes and the assessment of the natural history of diseases or conditions as well as measurements of association between hospital and patient characteristics by applying quantitative analysis to a large database. Additionally, a population-based retrospective cohort design can help to minimize selection bias, as the study population is drawn from a defined geographic area or population, rather than a select group of individuals (Xiaofeng et al., 2020)

DATA SOURCES

This study uses the HCUP KID dataset (2019), developed through a Federal-State-Industry partnership in sponsorship by AHRQ (HCUP, 2022). HCUP data are created for billing and research purposes and is based on administrative data to inform policies nationwide (HCUP, 2022). KID is the largest public pediatric inpatient, all-payer database and contains approximately 3 million weighted pediatric discharges each year, while weighted it covers approximately 7 million hospitalizations (HCUP, 2022).

STUDY POPULATION

This study utilizes a population-based retrospective cohort design which allows for the measurement of outcomes and the relationship between variables. The population set available for the year 2019 encompasses national estimates of hospital inpatient stays for patients 21 and younger (HCUP, 2022). The number of states included in the KID database are 48 plus the District of Columbia sampled from 4,000 U.S. community hospitals including non-federal, short-term, specialist and general hospitals yet excludes rehabilitation hospitals and those as attachment units of other institutions (HCUP, 2022). The KID database has been available every three years beginning from 1997 to 2012 and from 2016 to 2019, however it was not available for the year 2015 due to the transition to ICD-10-CM/PCS coding, which is utilized for this study (HCUP, 2022). The KID data file is structured around two elements the discharge-level files which include core files, severity file, and diagnosis and procedure groups files, while the hospital-level files include information on hospital characteristics (HCUP, 2022).

VARIABLES

Dependent Variables

The main dependent variables in this study are the three most prevalent PDIs in the year 2019, analyzed at the patient-level discharge level. These PDIs, their codes, and inclusion/exclusion categories are expanded upon in Table 2. As the PDIs were not counted as rates but rather measured at the patient level, they only included the numerator definition of the indicator, and therefore they are coded as whether they occurred:

NQI 03 Whether Neonatal Blood Stream Infection occurred (Yes=1; No=0)

PDI 09 Whether Postoperative Respiratory Failure occurred (Yes=1; No=0)

PDI 10 Whether Postoperative Sepsis Rate occurred (Yes=1; No=0)

In this study, three PDI’s were examined as an occurrence of AEs throughout the data as defined separately. Two of the PDIs (PDI 09 and 10) were designed to encompass all pediatric patients 17 years of age or younger, while one (NQI 03) was specific to neonatal cases. These indicators were chosen to cover the most commonly occurring indicators of PAE with regards to inpatient quality and patient safety at the encounter phase with medical care provided. As indicated by the AHRQ quality measurement and patient safety initiatives, each indicator contains a multitude of inclusion and exclusion codes and criteria based on expert delimitation. However, they are not intended for the purpose of creating an exhaustive grasp on all PAEs, rather as a relevant and dependable measure set extrapolated onto a uniquely pediatrically centered dataset, the KID database, for quality and safety purposes. It is worth noting that though the dataset contains patients younger than 21 years of age, many of the PDI's are specifically formulated to include those younger than 17 years of age, providing specialized insight into pediatric care.

Independent Variables

The independent variables for this study have been divided into two main categories, hospital characteristics, and patient characteristics as follows:

Hospital characteristics:

- HCUP KID defines hospital bed size as 1: Small, 2: Medium, 3: Large
- HCUP KID defines hospital location as 1: Rural 2: Urban nonteaching 3: Urban teaching
- HCUP KID defines hospital region as 1: Northeast 2: Midwest 3: South 4: West
- HCUP KID defines hospital ownership as 1: Government, non-federal (public) 2: Private, not- for-profit (voluntary) 3: Private, investor-owned (proprietary)

Patient Characteristics

- Age: HCUP KID defines age as 0-20.
- Neonatal: HCUP KID defines 0: Non-neonatal age at admission 1: Neonatal age at admission
- Gender: HCUP KID defines gender 0: Male 1: Female

- Race: KCUP KID defines race as 1: White 2: Black 3: Hispanic 4: Asian/Pacific Islander 5: Native American 6: Other
- Service line: HCUP KID defines service line as 1: Maternal and Neonatal 2: Mental health/substance use 3: Injury 4: Surgical 5: Medical
- Payment: HCUP KID defines payment source as 1: Medicare 2: Medicaid 3: Private insurance 4: Self-pay 5: No charge 6: Other
- Operation on record: HCU: KID defines previous operation on record as 0: No major operating room procedure on record 1: Major operating room procedure on record

STATISTICAL ANALYSIS

To conduct the required analysis with the application of AHRQ PDIs to HUCP KID database for the year 2019, the AHRQ QI SAS software that is created by AHRQ for this purpose must be used (AHRQ, 2020). For this study, the SAS QI® v2020, which has been adopted to be used with SAS Version 9.4 as a personal computer-based, single-user application, was utilized along with the specific population file for the v2020 provided by AHRQ (AHRQ, 2020). It is of note to mention that each AHRQ QI software generates numerators, denominators, observed and expected as well as risk-adjusted and smoothed rates for each QI model, with technical specifications for each indicator (AHRQ, 2020). For this study, only the numerator was taken into consideration as the framework for this study looks at individual incidents as the point of calculation and not the rate. These definitions and numerators can be found linked to Table 2 which highlights the specific criteria with the codes and procedures involved in each indicator to include covariates, and coefficients for risk adjustment models (AHRQ, 2020).

To model the dichotomous dependent variables, logistic regression analyses were used, computing three separate models to analyze three dependent variables to examine the factors associated with PDIs. The analysis focused on odds and adjusted odds rations (OR) in both bivariate and multivariate analyses. The statistical models utilized inpatient discharges as the units of analysis. Logistic regression allows for the estimation of odds ratios, which indicate the likelihood of an event occurring (e.g., the occurrence of a PDI) based on the values of the independent variables. This model, alongside the software, provided important insights into the associations between these variables to inform strategies for quality improvement and patient safety, as well as guide future research and interventions in pediatric healthcare settings.

ETHICAL CONSIDERATIONS

This study was exempted from institutional review board approval since it uses secondary data - a large database in which the subjects cannot be identified.

Table 2. AHRQ Hospital-level PDIs Description and Numerators (AHRQ, 2021)

PDI Number	PDI Name	PDI Description	PDI Numerator
NQI 03	Neonatal Blood Stream Infection Rate	Discharges with healthcare-associated blood stream infection per 1,000 discharges for newborns and outborns with birth weight of 500 grams or more but less than 1,500 grams; with gestational age between 24 and 30 weeks; or with birth weight of 1,500 grams or more and death, an operating room procedure, mechanical ventilation, or transferring from another hospital within two days of birth. Excludes discharges with a length of stay less than 3 days and discharges with a principal diagnosis of sepsis, or bacteremia, or newborn bacteremia.	Discharges, among cases meeting the inclusion and exclusion rules for the denominator, with either: • any secondary ICD-10-CM diagnosis codes for newborn sepsis (BSI5DX*) or • any secondary ICD-10-CM diagnosis codes for newborn septicemia or bacteremia codes requiring a separate organism code (BSI2DX*) and any secondary ICD-10-CM diagnosis codes for staphylococcal or Gram-negative bacterial infection (BSI3DX*)
PDI 09	Postoperative Respiratory Failure Rate	Postoperative respiratory failure (secondary diagnosis), prolonged mechanical ventilation, or reintubation cases per 1,000 elective surgical discharges for patients ages 17 and younger. Excludes cases with principal diagnosis for acute respiratory failure; cases with secondary diagnosis for acute respiratory failure present on admission; cases in which tracheostomy is the only operating room procedure or in which tracheostomy occurs before the first operating room procedure; cases with neuromuscular disorders or degenerative neurological disorders; cases with laryngeal, pharyngeal or craniofacial surgery; cases with craniofacial anomalies; cases with	Discharges, among cases meeting the inclusion and exclusion rules for the denominator, with either • any secondary ICD-10-CM diagnosis codes for acute respiratory failure; (ACURF2D*) • any-listed ICD-10-PCS procedure code for mechanical ventilation for greater than 96 consecutive hours (PR9672P*) that occurs zero or more days after the first major operating room procedure code (based on days from admission to procedure) • any-listed ICD-10-PCS procedure code for mechanical ventilation for 24-96

		esophageal resection, lung cancer, lung transplant cases; cases with respiratory or circulatory diseases; and obstetric discharges.	consecutive hours (PR9671P*) that occurs two or more days after the first major operating room procedure code (based on days from admission to procedure) • any-listed ICD-10-PCS procedure codes for a reintubation (PR9604P*) that occurs one or more days after the first major operating room procedure code (based on days from admission to procedure)
PDI 10	Postoperative Sepsis Rate	Postoperative sepsis cases (secondary diagnosis) per 1,000 surgery discharges for patients ages 17 years and younger. Includes metrics for discharges grouped by risk category. Excludes cases with a principal diagnosis of sepsis, cases with a secondary diagnosis of sepsis present on admission, cases with a principal diagnosis of infection (only if they also have a secondary diagnosis of sepsis), cases in which the procedure belongs to surgical class 4, neonates and obstetric discharges.	Discharges, among cases meeting the inclusion and exclusion rules for the denominator, with any secondary ICD-10-CM diagnosis codes for sepsis (SEPTI2D*). [NOTE: The numerator definition is identical for Risk Categories 1, 2, 3, 4, 9 and Overall].

CHAPTER 4: RESULTS

The following results section is an interpretation of the tables produced by running statistical analysis of the HCUP KID 2019 database with the unit of analysis at the individual patient level (Tables 5-6 NQI03, Tables 7-8 PDI09, Tables 9-10 PDI10). Each row in the tables represents an individual patient, with the variables capturing specific characteristics for each patient. Since the results are based on individual patient characteristics, outcomes, and hospital characteristics, they provide insights into the relationships and associations at the patient level. Properly acknowledging the individual patient unit of analysis ensures accurate and meaningful interpretations that inform clinical practice, healthcare policies, and targeted interventions for individual patients throughout the healthcare system.

The chapter will be divided into sections corresponding with the findings of the analysis conducted utilizing logistic regression for bivariate and multivariate analysis as follows:

- Descriptive Statistics: 2019
- Results: Associations between HCUP KID database for the year 2019 and NQI 03 Logistic Regression Bivariate & Multivariate Analysis
- Results: Associations between HCUP KID database for the year 2019 and PDI 09 Logistic Regression Bivariate & Multivariate Analysis
- Results: Associations between HCUP KID database for the year 2019 and PDI 10 Logistic Regression Bivariate & Multivariate Analysis

Descriptive Statistics: 2019

The descriptive analysis of the HCUP KID dataset (2019) provides valuable insights into the distribution and characteristics of hospitals and patients in the sample. The analysis includes the three main categories of the independent variables: hospital characteristics such as bed size, location, region, and ownership; patient characteristics like gender, race, service line, payment source, and the presence of operations, and patient outcomes, including mortality rates, hospital births, and the likelihood and extent of loss of function. Descriptive statistics such as the mean and standard deviation for age at admission and length of stay, were also reported offering a snapshot of the age range and duration of hospital stays for patients. Together, these findings serve as a foundation for understanding the profile of hospitals and patients under consideration and pave the way for further analysis and interpretation of the data.

Hospital Characteristics: Most hospitals in the sample were classified as large (60.7%), followed by medium (24.0%) and small (15.2%) in terms of bed size. Regarding location, most hospitals were classified as urban teaching hospitals (82.3%), followed by urban non-teaching hospitals (11.6%) and rural hospitals (6.1%). In terms of hospital region, the largest proportion was in the South (38.3%), followed by the West (22.0%), Midwest (22.6%), and Northeast (17.1%). Hospital ownership was predominantly private, not-for-profit entities (77.1%), with public hospitals accounting for 11.8% and private, investor-owned hospitals accounting for 11.0%.

Patient Characteristics: The mean age of patients at admission was (5.58) years, with a minimum age of 0 years and a maximum age of 20 years (standard deviation = 7.574). Approximately 51.4% of patients in the sample were female, while 48.6% were male. The largest racial group among patients was White (45.6%), followed by Black (16.6%), Hispanic (19.7%), Asian/Pacific Islander (4.0%), Native American (.9%), and Other (6.1%). The most common service line for hospitals in the sample was Maternal and Neonatal (55.6%), followed by Medical (27.4%), Mental health/substance use (6.8%), Surgical (7.1%), and Injury (3.2%). Regarding payment source, many patients had Medicaid (50.7%), followed by private insurance (41.1%), self-pay (4.3%), Medicare (0.3%), other (3.3%), and no charge (0.1%). Most patients in the sample did not have any operation recorded (88.0%), while the remaining (12.0%) underwent a major operation.

Dependent Variables: regarding dependent variables, the QIs in question (NQI 03, PDI 09, PDI 10) were taken at the numerator level to produce events/occurrences rather than a rate. The analysis conducted using the FREQ Procedure on the KID 2019 database, specifically examining the neonatal population segmented by age (AGE_NEONATE), revealed that most neonates, approximately 78.61%, did not display NBSI, amounting to 1,833,049 cases. Conversely, a significant proportion of the neonatal population, accounting for 21.39%, did exhibit NBSI, totaling 498,829 cases. These statistics offer valuable insights into the occurrence of NBSI among neonates in the specified year's database as it solely focuses on the neonatal population and not pediatric patients. It is worth noting that there were 14 missing cases in this analysis.

Regarding PDI 09 data, it was found that there were 4,214,198 cases where PORF was absent and 351,201 cases where it was present. The corresponding percentages were calculated as follows: PORF absent accounted for 92.31% of all cases while PORF present represented 7.69%. For PDI 10 data, there were a total of 3,987,774 cases where POS was absent and 577,625 cases where it was present. The percentage breakdown indicated that POS absent constituted approximately 87.35% of all cases while POS present represented around12.65%. It is important to mention that both variable indicators had a total of 5 ,637 missing values.

Overall, these descriptive statistics provide a comprehensive overview of both hospital and patient distribution and characteristics within our sample. These findings contribute to our understanding of hospital and patient profiles under consideration and lay the foundation for further analysis and interpretation of the data.

The FREQ Procedure Neonatal Blood Stream Infection in the KID 2019 database taken from the neonatal population (AGE_NEONATE)

NBSI	Frequency	Percent	Cumulative Frequency	Cumulative Percent
NBSI abscent	1833049	78.61	1833049	78.61
NBSI present	498829	21.39	2331878	100.00

Frequency Missing = 14

The FREQ Procedure of Postoverative Resperatory Failure in the KID 2019 database

PORF	Frequency	Percent	Cumulative Frequency	Cumulative Percent
PDI 09 abscent	4214198	92.31	4214198	92.31
PDI 09 present	351201	7.69	4565399	100.00

Frequency Missing = 5637

The FREQ Procedure of Postoverative Sepsis in the KID 2019 database

POS	Frequency	Percent	Cumulative Frequency	Cumulative Percent
PDI 10 abscent	3987774	87.35	3987774	87.35
PDI 10 present	577625	12.65	4565399	100.00

Frequency Missing = 5637

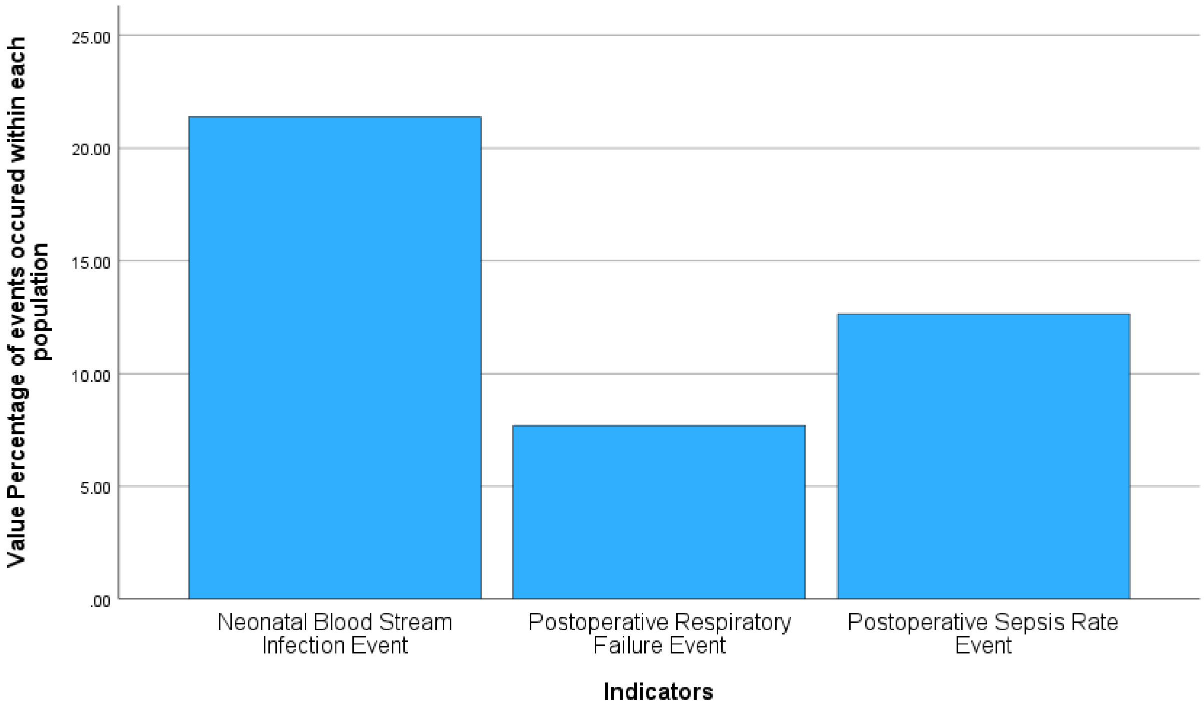

Figure 1. Frequency Tables for NBSI, PORF and POS within their respective populations as found in the 2019 KID database

Table 3. Descriptive analysis of the overal HCUP KID database independent variables, 2019

Hospital characteristics				
Variable Name	Level	Number of observations	Percent %	Missing %
Hospital bed size	Small	470770	15.2	0.0
	Medium	742057	24.0	
	Large	1876456	60.7	
Hospital location	Rural	189298	6.1	0.0
	Urban nonteaching	356963	11.6	
	Urban teaching	2543022	82.3	
Hospital region	Northeast	529073	17.1	0.0
	Midwest	696645	22.6	
	South	1183705	38.3	
	West	679860	22.0	
Hospital ownership	Public	365784	11.8	0.0
	Private, not for profit	2382758	77.1	
	Private, investor owned	340741	11.0	
Patient Characteristics				
Gender	Female	1587394	51.4	0.0
	Male	1500745	48.6	
Race	White	1407652	45.6	7.2
	Black	513619	16.6	
	Hispanic	607329	19.7	
	Asian/Pacific Islander	123698	4.0	
	Native American	26306	.9	
	Other	188042	6.1	
Service line	Maternal and Neonatal	1716825	55.6	0.0
	Mental health/substance use	209939	6.8	
	Injury	97434	3.2	
	Surgical	219576	7.1	
	Medical	845509	27.4	
Payment source	Medicare	10554	0.3	0.1
	Medicaid	1567452	50.7	
	Private insurance	1270547	41.1	
	Self-pay	131918	4.3	
	No charge	3843	0.1	
	Other	100660	3.3	
Operation on record	No Operation in record	2718390	88.0	0.0
	Major operating on record	370893	12.0	

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Age in years at admission	3089283	0	20	5.58	7.574
Valid N (listwise)	3089081				

Results: Associations between HCUP KID database for the year 2019 and NQI 03 Logistic Regression Bivariate & Multivariate analysis

In the bivariate logistic regression analysis, several patient and hospital characteristics were examined for their association with events of NBSI. With the sample population being restricted to the Neonate variable, the results revealed distinct relationships that pertain to that age of classification.

For patient characteristics, gender did not reveal a significant association (p=0.5876), indicating that there was no significant difference in the odds of infection between genders.

Regarding race, it was found to be strongly associated with NBSI events (p < 0.0001). The variable showed variations among different racial categories, when compared to the reference category "White," all other races displayed significantly higher odds ratios. For instance, the OR for Black patients was 1.453 (95% CI: 1.440-1.467), indicating 45.3% higher odds of infection compared to Whites. Whereas Hispanic patients (OR=1.351; 95% CI: 1.339 to 1.363) showed 35.1% higher odds of infection compared to Whites. Moreover, while Asian/Pacific islanders (OR=1.421; 95% CI: 14.01 to 1.442) showed 42.1% higher odds of infection compared to Whites, Native Americans (OR=0.530; 95% CI: 0.508 to 0.533) showed an inverse relationship with 53% lower odds of infection compared to Whites. Other races (OR=1.314; 95% CI: 1.297 to 1.331) showed 31.4% increase odds of infection.

In terms of service line, indicating the type of medical service provided, a significant association with NBSI was found (p < 0.0001, p <.5 Injury), except for Mental Health/Substance abuse (p=0.2912) when compared to the “Medical” service line. The odds ratio (OR) for the "Surgical" service line was particularly high at 1.783 (95% CI: 1.686 to1.886), indicating a significantly higher risk 78.3% compared to the reference category Medical. Maternal and

Neonatal services showed the lowest odds of infection (OR=0.585; 95% CI: 0.567 to 0.603) with 58.5% lower odds of infection when compared to Medical, followed by Injury (OR=1.266; 95% CI: 1.058 to 1.515) with a higher odd of infection amounting to 26.6% when compared to Medical.

Regarding payment source, significance was associated with NBSI when compared to "Self-pay" ($p < 0.0001$), where Medicare (OR=0.668; 95% CI: 0.619 to 0.720) showed 33.2% lower odds of infection. No charge (OR=0.579; 95% CI: 0.523 to 0.640) also showed a 42.1% lower odds of infection when compared to Self-pay, whereas Private Insurance (OR=1.526; 95% CI: 1.501 to 1.551), Medicaid (OR=1.305; 95% CI: 1.283 to 1.326) and Other (OR=1.577; 95% CI: 1.539 to 1.617) all showed higher odds of infection (52.6%, 30.5%, 57.7% respectively) when compared to the odds of infection of Self-pay patients.

Regarding Major operating room procedure, Neonate patients had a significantly higher odds (OR=1.980; 95% CI: 1.932 to 2.029) of infection when compared to patients without such procedures. This amounted to a nearly twofold 98% higher odds of infection, drawing attention to the concentration of risk present in operative circumstances.

As it came to hospital characteristics, all were found to be significantly associated with NBSI ($p < 0.0001$). Hospital bed size demonstrated a significant association with Small-sized hospitals showing an odds ratio of 0.442 (95% CI: 0.438-0.446), indicating a 55.8% lower likelihood of infection events when compared to the reference, Large-sized hospitals. Medium-sized hospitals had an OR of 0.755 (95% CI: 0.749-0.760), representing a 24.5% lower risk. These findings suggest that larger hospitals may face higher infection risks compared to smaller and medium-sized hospitals.

Hospital location also displayed a significant relationship with NBSI. Rural hospitals had the lowest OR of 0.074 (95% CI: 0.072-0.075), indicating a 92.6% lower risk of infection events compared to urban teaching hospitals (reference category). Urban nonteaching hospitals had an OR of 0.466 (95% CI: 0.461-0.470), signifying a 53.4% lower risk, when compared to urban teaching hospitals, showcasing the importance of considering hospital location when looking at neonatal infection.

Regarding hospital location, the odds ratios for the Northeast, Midwest, and South regions were estimated to be 0.929 (95% CI: 0.919-0.939), 0.787 (95% CI: 0.779-0.795), and 1.108 (95% CI: 1.099-1.118), respectively. These figures represent a 7.1% lower risk in the Northeast, a 21.3% lower risk in the Midwest, and an 10.8% higher risk in the South, compared to the West (reference category).

Furthermore, hospital ownership exhibited a significant relationship with NBSI. Public hospitals had an odds ratio of 0.725 (95% CI: 0.715-0.735), indicating a 27.5% lower risk compared to the Private- investor owned. Private, not-for-profit hospitals had an odds ratio of 1.025 (95% CI: 1.015-1.035), suggesting a 2.5% increased risk when compared to Private-investor-owned hospitals. These results imply that hospital ownership may influence infection risks, with public hospitals showing a lower risk compared to private, not-for-profit hospitals.

Table 4. NQI 03 Neonatal Blood Stream Infection Events (PPNQ03), Logistic Regression (Bivariate analysis) for patient characteristics, 2019

Patient Characteristics								
Variables		Estimate	SE	Wald Chi-Square	P-value	OR	Wald 95% confidence limits for OR	
Gender	Female	-0.0909	0.00231	1544.9792	0.5876	0.998	0.992	1.005
Age								
Race	White*							

	Black	0.3737	0.00474	6210.2915	<.0001	1.453	1.440	1.467
	Hispanic	0.3005	0.00456	4335.7171	<.0001	1.351	1.339	1.363
	Asian/Pacific Islander	0.3514	0.00731	2309.3090	<.0001	1.421	1.401	1.442
	Native American	-0.6356	0.0211	905.0704	<.0001	0.530	0.508	0.552
	Others	0.2732	0.00656	1735.7776	<.0001	1.314	1.297	1.331
Service line	Maternal and Neonatal	-0.5369	0.0154	1212.1621	<.0001	0.585	0.567	0.603
	Mental health/substance use	0.2149	0.2036	1.1139	0.2912	1.240	0.832	1.848
	Injury	0.2358	0.0915	6.6453	0.0099	1.266	1.058	1.515
	Surgical	0.5785	0.0286	409.9134	<.0001	1.783	1.686	1.886
	Medical*							
Payment Source	Medicare	-0.4039	0.0385	109.8998	<.0001	0.668	0.619	0.720
	Medicaid	0.2659	0.00837	1009.4189	<.0001	1.305	1.283	1.326
	Private insurance	0.4226	0.00837	2548.9116	<.0001	1.526	1.501	1.551
	No charge	-0.5472	0.0518	111.5880	<.0001	0.579	0.523	0.640
	Other	0.4556	0.0126	1304.3793	<.0001	1.577	1.539	1.617
	Self-pay *							
Operation on record	Major operating room procedure on record	0.6831	0.0125	3003.8294	<.0001	1.980	1.932	2.029

Table 5 (continue). NQI 03 Neonatal Blood Stream Infection Events (PPNQ03), Logistic Regression (Bivariate analysis) for hospital characteristics.

Hospital Characteristics								
Variables		Estimate	SE	Wald Chi-Square	P-value	OR	Wald 95% confidence limits for OR	
Hospital bed size	Small	-0.8163	0.00485	28347.8775	<.0001	0.442	0.438	0.446
	Medium	-0.2816	0.00389	5232.2092	<.0001	0.755	0.749	0.760
	Large*							
Hospital location	Rural	-2.6062	0.0106	60150.4947	<.0001	0.074	0.072	0.075
	Urban nonteaching	-0.7646	0.00466	26946.8518	<.0001	0.466	0.461	0.470
	Urban teaching*							
Hospital region	Northeast	-0.0741	0.00555	178.5115	<.0001	0.929	0.919	0.939
	Midwest	-0.2399	0.00509	2217.5831	<.0001	0.787	0.779	0.795
	South	0.1026	0.00435	556.8232	<.0001	1.108	1.099	1.118
	West *							
H-ownership	Public	-0.3219	0.00690	2177.1313	<.0001	0.725	0.715	0.735
	Private, not- profit	0.0247	0.00499	24.5644	<.0001	1.025	1.015	1.035

	Private, investor-owned*							

Following along with the multivariate analysis, this study sought to present associations with the variables while controlling for other factors. The associations for patient characteristics remained largely consistent, though gender (female) did show a significant association (P= 0.0158) with an adjusted odds ratio (AOR) of 1.009 (95% CI: 1.002-1.015), suggesting a 0.9% increased risk compared to males. This showed that there is a statistically significant difference between males and females in terms of infection odds when other variables are controlled for.

In terms of race, all races showed significant associations to NBSI when compared to White race and controlling for other variables. Being Black was associated with 16.6% higher odds of infection (AOR=1.166; 95% CI: 1.154 to 1.178) when comparing to White and controlling for other variables, while Hispanics had 7.7% higher odds than Whites when controlling for other variables (AOR= 1.077; 95% CI: 1.066 to 1.087) and Asian/Pacific Islander had 4.3% higher odds (AOR= 1.043; 95% CI: 0.962 to 0.990) when compared to White patients and controlling for other variables. Others was associated with 5.2% higher odds when compared to Whites (AOR=1.052; 95% CI: 1.038 to 1.066), while Native American (AOR=0.795; 95% CI: 0.761 to 0.831) showed an inverse relationship with 20.5% lower odds of infection when compared to Whites and controlling for other variables; remaining consistent with the findings of the bivariate analysis. These findings highlight the prominence of certain racial disparities in the risk of infection.

Examining the service line, Mental health/Substance use (p= 0.5706) remained insignificant as was in the bivariate analysis, however “Injury” service line (p= 0.6389) also became insignificant when compared to the “Medical” service line and controlling for other variables. Maternal and Neonatal services, however, showed a significant association with NBSI events with an AOR of (0.682; 95% CI: 0.661 to 0.704), indicating 31.8% lower odds of infection when comparing to the medical service line and controlling for other variables. Surgical service line also showed significance, with AOR of (0.929; 95% CI: 0.871 to 0.991) and 7.1% lower odds of infection than medical service lines and controlling for other variables.

Moving on to payment sources, when compared to Self-pay and controlling for other variables, all payment sources showed significance ($p<.0001$) with NBSI events. Both Medicare (AOR= 0.672; 95% CI: 0.621 to 0.727) and No charge (AOR= 0.670; 95% CI: 0.603 to 0.744) displayed 32.8% lower odds of infection. On the other hand, Medicaid (AOR= 1.079; 95% CI: 1.060 to 1.098) Private Insurance (AOR= 1.228; 95% CI: 1.207 to 1.250) and Other (AOR= 1.361; 95% CI: 1.326 to 1.397) showed higher odds of infection (7.9%, 22.8%, 36.1%, respectively). These findings mirror those of the bivariate analysis and suggest that certain payment sources may confer a protective effect against infection.

Meanwhile, a Major operating room on record (AOR= 1.457; 95% CI: 1.414 to 1.501) was associated with 45.7% higher odds of infection when compared to no major operation on record and controlling for other variables, further mirroring bivariate findings and consistently showing the vulnerability of repeat patients to infection.

Among hospital characteristics, small and medium bed sized hospitals (AOR= 0.421; 95% CI: 0.417 to 0.426, AOR=0.730 95% CI: 0.724 to 0.736, respectively) consistently showed significantly ($p<.0001$) lower odds of infection (57.9%, 27%, respectively) when compared to large hospitals and controlling for other variables which could be related to the type of services offered in small and medium sized hospitals as opposed to larger ones. Nonetheless, hospital location also played a significant role ($p<.0001$) with Rural (AOR= 0.672; 95% CI: 0.621 to 0.727) and Urban nonteaching (AOR= 0.672; 95% CI: 0.621 to 0.727) both showing lower odds

(92.4%, 53.9%, respectively) of infection when compared to Urban teaching hospitals. These results were consistent with the bivariate analysis and displayed an increased risk in environments associated with urbanism and teaching.

When examining hospital region (all p<,0001), the South region (AOR= 1.141; 95% CI: 1.131 to 1.152) was associated with 14.1% higher odds of infection compared to the reference category (West region) whereas the Northeast (AOR= 0.816; 95% CI: 0.807 to 0.826), and the Midwest (AOR= 0.899; 95% CI: 0.889 to 0.909) were found to be significantly associated with lower odds of infection (18.4%, 10.1%, respectively) when compared to the West and controlling for other variables.

Regarding hospital ownership both Public (AOR= 0.733; 95% CI: 0.723 to 0.744) and Private not-for-profit (AOR= 0.948; 95% CI: 0.948 to 0.968) hospitals were found to be significantly associated (p<.0001) with lower odds of infection (26.7%, 4.2%, respectively) than Private- investor-owned hospitals when controlling for other variables. It is of note that the relationship associated with Private not-for-profit hospitals became inverse when controlling for other variables in the multivariate analysis, suggesting that there are other factors impacting the relationship with infection events in these types of hospitals.

The findings of the above bivariate and multivariate logistic regression analyses examined the association between various patient and hospital characteristics and the occurrence of NBSI events in neonates. In the bivariate analysis, gender did not show a significant association with NBSI events, while race, service line, payment source, major operating room procedure, hospital bed size, hospital location, hospital region, and hospital ownership were all significantly associated with NBSI events. When controlling for other factors in the multivariate analysis, the associations for patient characteristics remained largely consistent. Gender (female) showed a significant association with a slightly increased risk of NBSI compared to males. Race, service line, payment source, major operating room procedure, hospital bed size, hospital location, hospital region, and hospital ownership all maintained significant associations with NBSI events. However, there were some changes in the magnitude of the associations in the multivariate analysis compared to the bivariate analysis.

Both the bivariate and multivariate analyses showed that various patient and hospital characteristics have significant associations with NBSI events, suggesting that these characteristics play a role in the occurrence of NBSI and should be considered when considering preventative measures. Nonetheless, there were several possible reasons for the relationships observed between the variables and NBSI events. For patient characteristics, the significant association between race and NBSI events may be due to differences in genetic susceptibility, access to healthcare, or exposure to risk factors among different racial groups. The associations with payment source may reflect differences in healthcare access, quality of care, or underlying health conditions associated with different insurance types.

In terms of hospital characteristics, the significant associations with hospital bed size and location could be attributed to differences in resources, staffing, infection control measures, or patient volume. The relationships with hospital region may reflect regional differences in infection control practices, healthcare infrastructure, or patient demographics. The association with hospital ownership may be influenced by differences in funding, management practices, or quality control measures.

Overall, these findings suggest that patient and hospital characteristics play a significant role in NBSI events and addressing these factors could help reduce the risk of infection in neonates.

Table 6. NQI 03 Neonatal Blood Stream Infection Events (PPNQ03), Logistic Regression (Multivariate analysis).

Variable		Estimate	SE	Wald Chi-Square test	P-value	Adjusted OR	Wald 95% Confidence Limits for AOR	
Intercept		-0.4337	0.0194	501.5069	<.0001	0.648	-	-
Age								
Sex	Female	0.00847	0.00351	5.8222	0.0158	1.009	1.002	1.015
	Male*							
Race	White*							
	Black	0.1535	0.00517	881.5084	<.0001	1.166	1.154	1.178
	Hispanic	0.0739	0.00503	215.7485	<.0001	1.077	1.066	1.087
	Asian/Pacific Islander	0.0423	0.00759	31.0443	<.0001	1.043	0.962	0.990
	Native American	-0.2294	0.0225	103.8504	<.0001	0.795	0.761	0.831
	Others	0.0508	0.00683	55.2842	<.0001	1.052	1.038	1.066
Service line	Maternal and Neonatal	-0.3831	0.0161	567.0396	<.0001	0.682	0.661	0.704
	Mental health/substance use	-0.1174	0.2069	0.3217	0.5706	0.889	0.593	1.334
	Injury	-0.0435	0.0928	0.2201	0.6389	0.957	0.798	1.148
	Surgical	-0.0737	0.0329	5.0169	0.0251	0.929	0.871	0.991
	Medical*							
Payment Source	Medicare	-0.3971	0.0402	97.5495	<.0001	0.672	0.621	0.727
	Medicaid	0.0759	0.00881	74.1780	<.0001	1.079	1.060	1.098
	Private insurance	0.2057	0.00884	542.0145	<.0001	1.228	1.207	1.250
	No charge	-0.4010	0.0538	55.6353	<.0001	0.670	0.603	0.744
	Other	0.3081	0.0133	538.8821	<.0001	1.361	1.326	1.397
	Self-pay *							
Operation on record	Major operating room procedure on record	0.3762	0.0153	605.3762	<.0001	1.457	1.414	1.501
Hospital bed size	Small	-0.8640	0.00502	29669.8567	<.0001	0.421	0.417	0.426
	Medium	-0.3144	0.00408	5930.7825	<.0001	0.730	0.724	0.736
	Large*							
Hospital location	Rural	-2.5734	0.0108	57294.8291	<.0001	0.076	0.075	0.078

Variable		Estimate	SE	Wald Chi-Square test	P-value	Adjusted OR	Wald 95% Confidence Limits for AOR	
	Urban nonteaching	-0.7742	0.00477	26318.7635	<.0001	0.461	0.457	0.465
	Urban teaching*							
Hospital region	Northeast	-0.2032	0.00591	1181.1937	<.0001	0.816	0.807	0.826
	Midwest	-0.1065	0.00558	364.6463	<.0001	0.899	0.889	0.909
	South	0.1321	0.00474	777.7836	<.0001	1.141	1.131	1.152
	West *							
H-ownership	Public	-0.3099	0.00735	1780.3272	<.0001	0.733	0.723	0.744
	Private, not- profit	-0.0433	0.00536	65.1875	<.0001	0.958	0.948	0.968
	Private, investor-owned*							

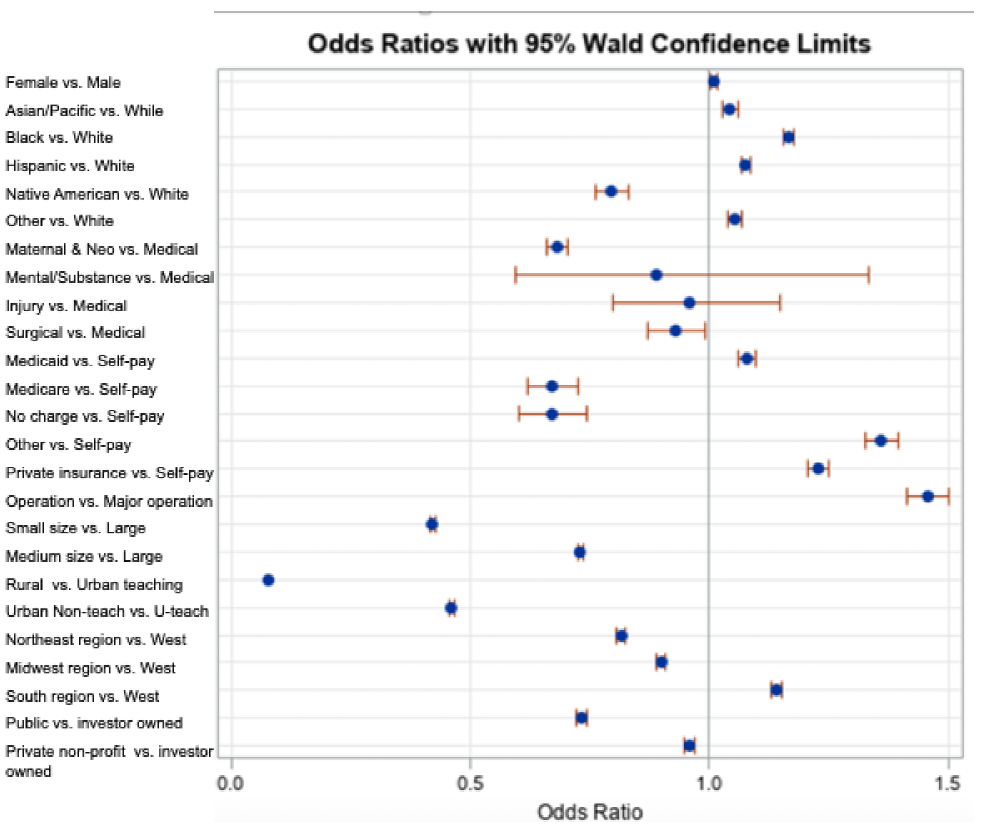

Figure 2. Odds Ratio with 95% Wald Confidence Limits Associated with NBSI (multivaria

Results: Associations between HCUP KID database for the year 2019 and PDI 09 Logistic Regression Bivariate & Multivariate analysis

The logistic regression analyses used to examine the associations between patient characteristics, hospital characteristics, and the occurrence of PORF (PDI 09), showcased significant associations for these factors and the likelihood of PORF in the bivariate analysis.

Several variables were found to be significantly associated with PORF. Regarding patient characteristics, gender was significantly associated with PORF ($p < .0001$). Female patients had lower odds of experiencing PORF, with an OR of 0.906 (95% CI: 0.900 - 0.913), representing a 9.4% reduction in the odds compared to males. Age was also strongly associated with PORF ($p < 0.0001$). For each year increase in age, the odds of PORF increased by a factor of 1.010 (95% CI: 1.010 - 1.011), representing a 1.0% increase in odds for each additional year.

Race exhibited a significant predictor of PORF ($p < .0001$) when compared to the White category. All races, except for Native American, exhibited higher odds of PORF events, amongst whom, Asian/Pacific Islander patients exhibited the highest odds of 20.5% (AOR: 1.205, 95% CI: 1.184 - 1.226) when compared to White patients. Black patients had 10.7% higher odds (AOR: 1.107, 95% CI: 1.096 - 1.118), while Hispanic patients had 9.4% higher odds (AOR: 1.094, 95% CI: 1.083 - 1.104) when compared to White patients. "Other" race patients had 11.6% higher odds (AOR: 1.116, 95% CI: 1.099 - 1.133). Whereas Native American patients had 7.0% lower odds (AOR: 0.931, 95% CI: 0.900 - 0.963) of experiencing PORF events when compared to Whites.

Among Service lines, all were significantly associated with PORF (all, $p < 0.0001$). Patients in the Maternal and Neonatal service line had the lowest odds of PORF with an OR of 0.512 (95% CI: 0.508 to 0.517), indicating a 48.8% lower risk compared to those in the Medical service line. Patients in Mental health/substance abuse followed with 36.6% lower odds of PORF events (AOR= 0.634, 95% CI: 0.624 – 0.645). Meanwhile, patients in the Surgical service line had the highest odds of PORF, with 91.5% higher odds (AOR: 1.915, 95% CI: 1.893 - 1.938) when compared to the Medical service line. While the Injury service line had 17.4% higher odds (AOR: 1.174, 95% CI: 1.153 to 1.196) when compared to the Medical service line.

Payment sources, on the other hand, showed that Medicare and No Charge were not associated with PORF events when compared to Self-pay. Nonetheless, Medicaid had 5.2% higher odds (AOR: 1.052, 95% CI: 1.033 - 1.071), Private Insurance had 22.7% higher odds (AOR: 1.227, 95% CI: 1.205 - 1.249), while “Other" had 39.6% higher odds (AOR: 1.396, 95% CI: 1.362 to 1.431) of experiencing PORF events when compared to Self-pay payment sources.

Moreover, having a Major Operation on record had significantly higher odds of PORF with an AOR of 1.905 (95% CI: 1.887 to 1.922), representing a 90.5% increase in odds compared to no operations on record.

Regarding hospital characteristics (all $p<.0001$), "Small" hospitals had 33.7% lower odds (AOR: 0.663, 95% CI: 0.656 - 0.669) and Medium sized hospitals had 37.7% lower odds (AOR: 0.623, 95% CI: 0.617 - 0.629) when compared to Large hospitals. Moreover, patients admitted to Rural hospitals had 72.2% lower odds (AOR: 0.278, 95% CI: 0.274 - 0.282) of PORF when compared to "Urban nonteaching" hospitals had 66.7% lower odds (AOR: 0.333, 95% CI: 0.328 - 0.337) when compared to Urban-teaching hospitals.

Hospital region also played a significant role in associations with PORF when compared to the West region. Hospitals in the Northeast region had 11.2% lower odds (AOR: 0.888, 95% CI: 0.878 - 0.898) of PORF events, while Midwest had 21.5% lower odds (AOR: 0.785, 95% CI:

0.777 - 0.793). Similarly, hospitals in the South had 18.8% lower odds (AOR: 0.812, 95% CI: 0.804 - 0.819) of PORF when compared to hospitals in the West region.

Furthermore, hospital ownership displayed significant impact on odds of PORF with patients in Public hospitals having 29.1% higher odds (AOR: 1.291, 95% CI: 1.272 - 1.311). and patients in Private, not-for-profit hospitals showcasing 40.8% higher odds (AOR: 1.408, 95% CI: 1.392 - 1.425) when compared to Private, investor-owned hospitals.

Table 7. PDI 09 Postoperative Respiratory Failure , Logistic Regression (Bivariate analysis) for patient characteristics, 2019

Patient Characteristics								
Variables		Estimate	SE	Wald Chi-Square	P-value	OR	Wald 95% confidence limits for OR	
Gender	Female	-0.0986	0.00363	736.9013	<.0001	0.906	0.900	0.913
Age		0.0104	0.000225	2133.8503	<.0001	1.010	1.010	1.011
Race	White*							
	Black	0.1014	0.00506	401.8005	<.0001	1.107	1.096	1.118
	Hispanic	0.0894	0.00479	348.7013	<.0001	1.094	1.083	1.104
	Asian/Pacific Islander	0.1862	0.00889	439.2702	<.0001	1.205	1.184	1.226
	Native American	-0.0712	0.0172	17.0715	<.0001	0.931	0.900	0.963
	Others	0.1096	0.00768	203.4330	<.0001	1.116	1.099	1.133
Service line	Maternal and Neonatal	-0.6686	0.00421	25193.0749	<.0001	0.512	0.508	0.517
	Mental health/substance use	-0.4558	0.00844	2916.9615	<.0001	0.634	0.624	0.645
	Injury	0.1608	0.00918	306.6860	<.0001	1.174	1.153	1.196
	Surgical	0.6499	0.00599	11754.9097	<.0001	1.915	1.893	1.938
	Medical*							
Payment Source	Medicare	0.0161	0.0323	0.2475	0.6188	1.016	0.954	1.083
	Medicaid	0.0504	0.00907	30.8501	<.0001	1.052	1.033	1.071
	Private insurance	0.2042	0.00912	500.9101	<.0001	1.227	1.205	1.249
	No charge	-0.0121	0.0485	0.0628	0.8022	0.988	0.898	1.086
	Other	0.3336	0.0127	687.4345	<.0001	1.396	1.362	1.431
	Self-pay *							
Operation on record	Major operating room procedure on record	0.6444	0.00469	18897.1766	<.0001	1.905	1.887	1.922

Table 8._ (continue) PDI 09 Postoperative Respiratory Failure , Logistic Regression (Bivariate analysis) for patient characteristics, 2019

Hospital Characteristics								
Hospital bed size		Estimate	SE	Wald Chi-Square	P-value	OR	Wald 95% confidence limits for OR	
	Small	-0.4113	0.00488	7113.9435	<.0001	0.663	0.656	0.669
	Medium	-0.4732	0.00458	10689.1566	<.0001	0.623	0.617	0.629
	Large*							
Hospital location	Rural	-1.2795	0.00754	28807.3557	<.0001	0.278	0.274	0.282
	Urban nonteaching	-1.1007	0.00678	26395.5212	<.0001	0.333	0.328	0.337
	Urban teaching*							
Hospital region	Northeast	-0.1187	0.00576	424.7343	<.0001	0.888	0.878	0.898
	Midwest	-0.2423	0.00532	2073.4857	<.0001	0.785	0.777	0.793
	South	-0.2085	0.00468	1985.7094	<.0001	0.812	0.804	0.819
	West *							
Hospital ownership	Public	0.2558	0.00760	1134.0179	<.0001	1.291	1.272	1.311
	Private, not- profit	0.3425	0.00609	3161.8351	<.0001	1.408	1.392	1.425
	Private, investor-owned*							

In the multivariate analysis, while adjusting for other variables several associations remained significant. Age retained its significance (p<.0001), yet the relationship became inverse with older patients having a 0.4% decrease in the odds for each additional year of PORF events (AOR = 0.996, 95% CI: 0.995 - 0.996) signifying the confounded factor age plays in this particular PAE. Female gender, originally associated with decreased odds of PORF in the bivariate analysis, lost its significance in the multivariate analysis (p=0.6919).

Regarding racial categories, many of the relationships also lost their significance when controlling for other variables, amongst them being patients of Black race or Other. Meanwhile, Hispanic, and Native American patients displayed an inverse relationship with 8.2% lower odds (AOR: 0.918, 95% CI: 0.909 - 0.928), and 5.2% (AOR: 1.052, 95% CI: 1.016 to 1.089) higher odds, respectively, when comparing to White patients and controlling for other variables.

Asian/Pacific islander patients were found to have 2.3% higher odds (AOR: 1.023, 95% CI: 1.005 to 1.041) when compared to White patients and controlling for variables.

Among service lines, the multivariate analysis echoed the bivariate analysis in many ways. Maternal and Neonatal services as well as Mental Health/Substance use both had lower odds of PORF when controlled for other variables. Maternal and Neonatal had 43.0% lower odds (AOR: 0.570, 95% CI: 0.565 to 0.576), and Mental Health/Substance had 32.9% lower odds (AOR: 0.671, 95% CI: 0.659 to 0.683) when compared to Medical service lines and controlling for other variables. Furthermore, Surgical services demonstrated 51.0% higher odds (AOR: 1.510, 95% CI: 1.478 to 1.544) of PORF events when compared to Medical services and controlling for other variables. Meanwhile, Injury service line was found to not be significantly associated with PORF events when compared to Medical.

In terms of payment source, Medicare and No charge remained insignificantly associated with PORF events when comparing to Self-pay and controlling for other variables. However, “Other” payment source was found to be significantly associated ($p<.0001$) with PORF with 7.9% higher odds (AOR: 1.079, 95% CI: 1.052 to 1.107) when compared to Self-pay and controlling for other variables. As for Medicaid payments, they had 5.7% lower odds (AOR: 0.943, 95% CI: 0.926 to 0.960), while Private Insurance had 5.5% higher odds (AOR: 1.055, 95% CI: 1.036 to 1.074) when compared to Self-pay and controlling for other variables.

As with the bivariate analysis Major operation on record remained a significant predictor of PORF ($p<.0001$) with 17.9% higher odds (AOR: 1.179, 95% CI: 1.157 - 1.201) when compared to no major operations and controlling for other variables.

With respect to hospital characteristics, Small hospitals had 25.1% lower odds (AOR: 0.749, 95% CI: 0.742 - 0.757), and Medium-sized hospitals had 29.2% lower odds (AOR: 0.708, 95% CI: 0.701 - 0.714) of PORF when compared to Large sized hospitals and controlling for other variables (both p<.0001). Hospital location and region also showed a significant association with PORF (all p<.0001), with Rural hospitals showcasing 68.3% lower odds (AOR: 0.317, 95% CI: 0.312 to 0.322) and Urban Nonteaching 60.6% lower odds (AOR: 0.394, 95% CI: 0.389 - 0.400) when comparing to Urban Teaching hospitals and controlling for other variables. Moreover, hospitals in the Northeast region were associated with 20.5% lower odds (AOR: 0.795, 95% CI: 0.786 - 0.805), while Midwest hospitals had 17.5% lower odds (AOR: 0.825, 95% CI: 0.816 - 0.834), and hospitals in the South region showed 13.7% lower odds (AOR: 0.863, 95% CI: 0.854 - 0.871) of PORF events when compared to the West region and controlling for other variables (all p<.0001).

Furthermore, hospital ownership was found to be positively associated with PORF, with Public hospitals displaying 14.6% higher odds (AOR: 1.146, 95% CI: 1.128 - 1.164), and Private non-for-profit hospitals 14.2% higher odds (AOR: 1.142, 95% CI: 1.128 - 1.156) when comparing to Private investor-owned hospitals and controlling for other variables.

The logistic regression analyses illuminated the multifaceted nature of PORF risk. While some associations remained consistent between the bivariate and multivariate analyses, some became inverse, and some fell out of significance. Overall, the analysis demonstrated significant associations between various patient characteristics, hospital characteristics, and the likelihood of PORF. In the bivariate analysis, factors such as gender, age, race, service line, payment source, having a major operation on record, and hospital characteristics all showed significant associations with PORF. However, in the multivariate analysis, some of these associations changed, suggesting that the relationship between certain variables and PORF may be confounded by other factors.

Race showed significant differences in PORF risk, with different racial categories having varying odds ratios compared to White patients. These associations were also subjected to inverse relationships when considering the simultaneous effects of multiple variables, which suggests a more nuanced understanding of the associations between the variables and merits more in-depth analysis.

It is of note that across both analysis, Medicare and no charge remained insignificant predictors of PORF, while private insurance seemed to have a positive influence on the odds regardless of variable control. This suggests that certain socioeconomic patient characteristics should be taken into consideration when assessing and mitigating PORF occurrence.

It is also of note when considering the type of medical complications that entail PORF as an AE; the highly operative nature of the PAE. This was reflected in the analysis with focus on Surgical services as a place of their occurrence, even when other factors are at play.

Furthermore, the type of operation on record was significantly associated with PORF as major operating room procedures on record were linked to higher odds of PORF across analysis. This suggests that more complex surgical procedures are associated with increased risk and encourages surgeons and healthcare providers to be particularly vigilant when managing high-risk surgeries, and to consider additional preventive measures.

Regarding hospital characteristics, smaller hospitals and hospitals in certain regions were associated with lower odds of PORF, reflecting he need for tailored interventions in different hospital settings to reduce PRF risk. Meanwhile, Public and Private non-profit hospitals consistently showed higher odds of PORF when compared to Private investor-owned hospitals across analysis; suggesting that certain hospital types may be more equipped with PORF prevention measures. Further highlighting the important role hospital characteristics play in the occurrence, management, and prevention of PORF.

Overall, the analysis highlights the complex and multifactorial nature of PORF. It demonstrates the importance of considering multiple patient and hospital characteristics when assessing the risk of PORF. The findings can inform healthcare providers and policymakers in identifying high-risk individuals and implementing strategies to reduce the occurrence of PORF.

Table 9. PDI 09 Postoperative Respiratory Failure Events (PPPD09), Logistic Regression (Multivariate analysis).

Variable		Estimate	SE	Wald test	P-value	Adjusted OR	Wald 95% Confidence Limits for IRR	
Intercept		-1.7917	0.0124	20964.6656	<.0001	0.167	-	-
AGE		-0.00418	0.000298	196.0796	<.0001	0.996	0.995	0.996
SEX	Female	0.00150	0.00379	0.1571	0.6919	1.002	0.994	1.009
	Male*							
RACE	White							
	Black	0.000486	0.00536	0.0082	0.9278	1.000	0.990	1.011
	Hispanic	-0.0850	0.00521	266.0689	<.0001	0.918	0.909	0.928
	Asian/Pacific Islander	0.0226	0.00914	6.1137	0.0134	1.023	1.005	1.041
	Native American	0.0508	0.0177	8.1824	0.0042	1.052	1.016	1.089
	Others*	0.00803	0.00789	1.0349	0.3090	1.008	0.993	1.024
Service line	Maternal and Neonatal	-0.5617	0.00471	14217.7550	<.0001	0.570	0.565	0.576
	Mental health/substance use	-0.3991	0.00884	2040.6849	<.0001	0.671	0.659	0.683
	Injury	0.0112	0.0102	1.2020	0.2729	1.011	0.991	1.032
	Surgical	0.4124	0.0111	1385.5081	<.0001	1.510	1.478	1.544
	Medical*							
Payment Source	Medicare	-0.0385	0.0329	1.3729	0.2413	0.962	0.902	1.026
	Medicaid	-0.0589	0.00927	40.3335	<.0001	0.943	0.926	0.960
	Private insurance	0.0533	0.00937	32.3885	<.0001	1.055	1.036	1.074
	No charge	-0.0325	0.0492	0.4366	0.5088	0.968	0.879	1.066

Variable		Estimate	SE	Wald test	P-value	Adjusted OR	Wald 95% Confidence Limits for IRR	
	Other	0.0759	0.0130	33.9742	<.0001	1.079	1.052	1.107
	Self-pay *							
Operation on record	Major operating room procedure on record	0.1643	0.00953	297.2510	<.0001	1.179	1.157	1.201
Hospital bed size	Small	-0.2887	0.00501	3321.6974	<.0001	0.749	0.742	0.757
	Medium	-0.3458	0.00470	5408.6080	<.0001	0.708	0.701	0.714
	Large*							
Hospital location	Rural	-1.1499	0.00777	21923.3961	<.0001	0.317	0.312	0.322
	Urban nonteaching	-0.9302	0.00692	18057.0116	<.0001	0.394	0.389	0.400
	Urban teaching*							
Hospital region	Northeast	-0.2290	0.00603	1443.3234	<.0001	0.795	0.786	0.805
	Midwest	-0.1925	0.00570	1138.1736	<.0001	0.825	0.816	0.834
	South	-0.1477	0.00499	875.6528	<.0001	0.863	0.854	0.871
	West *							
H-ownership	Public	0.1361	0.00784	301.7575	<.0001	1.146	1.128	1.164
	Private, not- profit	0.1328	0.00637	435.0090	<.0001	1.142	1.128	1.156
	Private, investor-owned*							

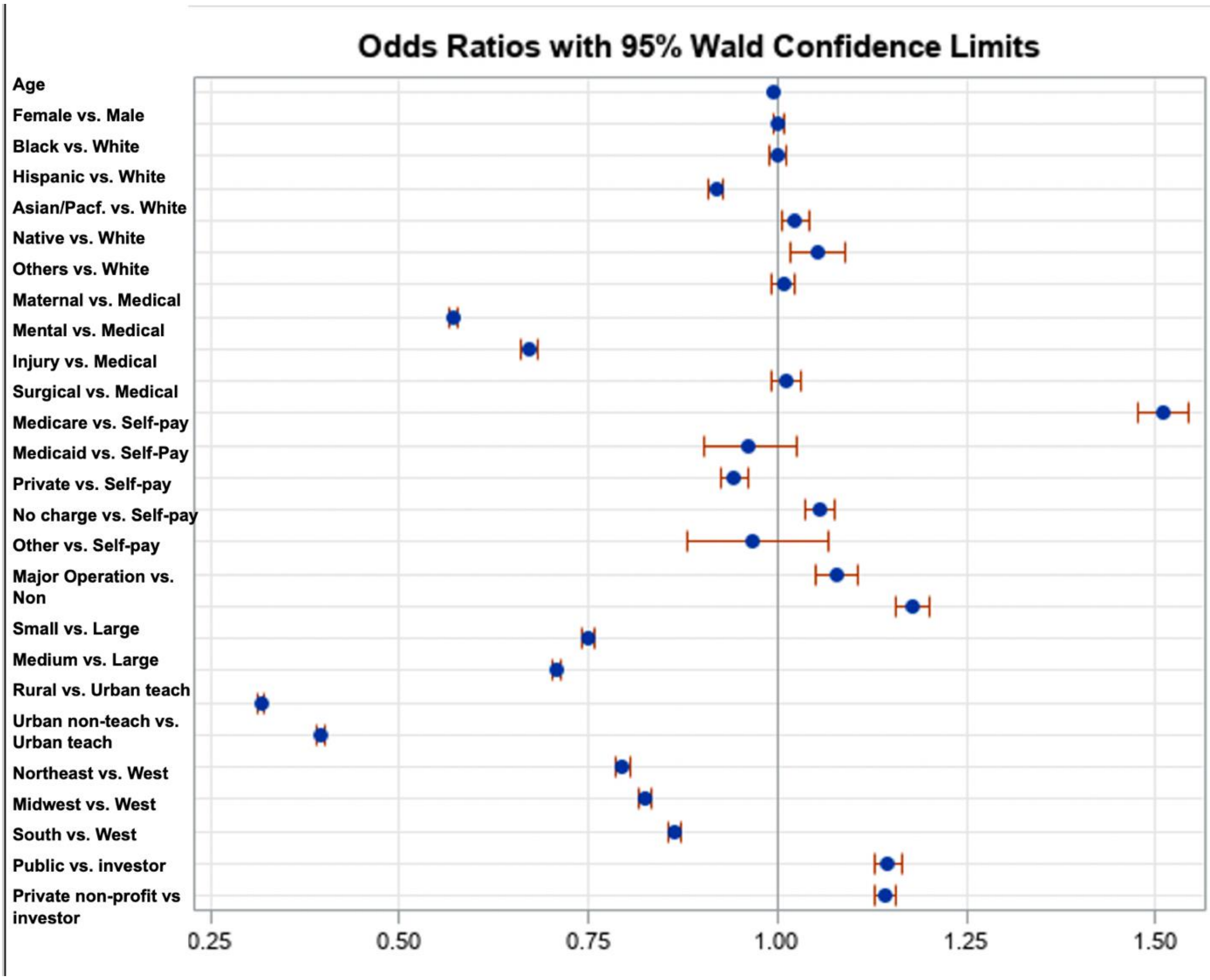

Figure 3. Independent variables Odds Ratio with 95% Wald Confidence Limits Associated with PORF (multivariate).

Results: Associations between HCUP KID database for the year 2019 and PDI 10 Logistic Regression Bivariate & Multivariate analysis

The results of the bivariate analysis which determined the relationship between patient characteristics and the occurrence of POS events, as measured by the PDI 10 variable, showed that female gender was found to be significantly associated with POS events. Females had 6.5% lower odds (OR = 0.935, 95% CI: 0.929 - 0.940) of experiencing POS compared to males ($p < .0001$). Age also demonstrated a positive association with POS events, with each one-unit increase in age corresponding to a 1.1% increase in odds (OR = 1.011, 95% CI: 1.010 - 1.011, $p < .0001$).

Among different races, significant disparities in odds of experiencing POS ($p<.0001$) were associated. Black patients had 12.1% higher odds (OR = 1.121, 95% CI: 1.112 - 1.130) compared to the reference group (White). Hispanic individuals had 16.2% higher odds (OR = 1.167, 95% CI: 1.185 - 1.206), while Asian/Pacific Islanders had 20.6% higher odds (OR = 1.206, 95% CI: 1.189 - 1.223) of experiencing POS events when compared to White patients. Native Americans, on the other hand, had 3.3% lower odds (OR = 0.967, 95% CI: 0.941 - 0.993, $p = 0.0132$), and the odds for the "Other" race category were 17.5% higher (OR = 1.192, 95% CI: 1.178 - 1.206).

Regarding the associated service lines, a significant difference in odds of POS were displayed. Patients in the Maternal and Neonatal service line had 37.9% lower odds of experiencing POS events when compared to the Medical service line (OR = 0.621, 95% CI: 0.617 - 0.625), while those in the Mental health/substance use services had 23.7% lower odds (OR = 0.773, 95% CI: 0.763 - 0.783). In contrast, patients in the Injury and Surgical service lines had 48.5% (OR = 1.485, 95% CI: 1.464 - 1.506) and 65.2% (OR = 1.652, 95% CI: 1.635 - 1.669) higher odds of experiencing POS, respectively ($p < .0001$ for all service lines).

Payment source also played a significant role in the odds of POS. Medicaid was associated with 6.0% higher odds (OR = 1.060, 95% CI: 1.045 - 1.075), and private insurance was associated with 15.9% higher odds (OR = 1.159, 95% CI: 1.142 - 1.175) when compared to Self-pay patients. No significant differences were observed for Medicare, No Charge, and Other payment sources compared to the reference group (Self-pay).

Regarding operation on record, specifically major operating room procedures, showed the strongest association with higher odds of experiencing POS events. Patients undergoing major operating room procedures had 65.6% higher odds (OR = 1.656, 95% CI: 1.643 - 1.669, $p < .0001$) compared to those without major procedures.

Meanwhile the analysis for hospital characteristics, showed that Hospital bed size played a significant difference in the odds of POS events. Small hospitals had 34.2% lower odds (OR = 0.658, 95% CI: 0.653 - 0.663), and medium-sized hospitals had 27.7% lower odds (OR = 0.723, 95% CI: 0.718 - 0.728) when compared to Large sized hospitals. These associations were highly statistically significant ($p < .0001$).

Regarding hospital location, rural hospitals had 67.7% lower odds (OR = 0.331, 95% CI: 0.328 - 0.335), and urban nonteaching hospitals had 53.1% lower odds (OR = 0.469, 95% CI: 0.464 - 0.473) of experiencing postoperative sepsis events compared to urban teaching hospitals. Both associations were highly significant ($p < .0001$).

Hospital region also demonstrated significant disparities in odds of POS. Hospitals in the Northeast, Midwest, and South regions had lower odds of POS when compared to hospitals in the West region. Northeast hospitals had 11.7% lower odds (OR = 0.883, 95% CI: 0.875 - 0.891), Midwest hospitals had 28.2% lower odds (OR = 0.718, 95% CI: 0.712 - 0.724), and

South hospitals had 22.4% lower odds (OR = 0.776, 95% CI: 0.771 - 0.782) when compared to the West. All associations were highly statistically significant (p < .0001).

Hospital ownership was also significantly associated with the odds of POS events. Public hospitals had 6.4% higher odds (OR = 1.064, 95% CI: 1.053 - 1.076), and private not-for-profit hospitals had 7.1% higher odds (OR = 1.074, 95% CI: 1.064 - 1.083) when compared to private investor-owned hospitals. Both associations were statistically significant (p < .0001).

Table 10. PDI 10 Postoperative Sepsis Events (PPPD10), Logistic Regression (Bivariate analysis) for patient characteristics

Patient Characteristics								
Variables		Estimate	SE	Wald Chi-Square	P-value	OR	Wald 95% confidence limits for OR	
Gender	Female	-0.0677	0.00291	539.4051	<.0001	0.935	0.929	0.940
Age		0.0108	0.000181	3546.3190	<.0001	1.011	1.010	1.011
Race	White*							
	Black	0.1141	0.00408	781.6890	<.0001	1.121	1.112	1.130
	Hispanic	0.1619	0.00380	1816.5881	<.0001	0.1619	1.167	1.185
	Asian/Pacific Islander	0.1870	0.00722	670.2620	<.0001	1.206	1.189	1.223
	Native American	-0.0339	0.0137	6.1485	0.0132	0.967	0.941	0.993
	Others	0.1755	0.00609	829.9686	<.0001	1.192	1.178	1.206
Service line	Maternal and Neonatal	-0.4766	0.00339	19776.536 2	<.0001	0.621	0.617	0.625
	Mental health/substance use	-0.2578	0.00653	1558.2293	<.0001	0.773	0.763	0.783
	Injury	0.3952	0.00730	2933.4005	<.0001	1.485	1.464	1.506
	Surgical	0.5018	0.00534	8835.5055	<.0001	1.652	1.635	1.669
	Medical*							
Payment Source	Medicare	0.0470	0.0252	3.4628	0.0628	1.048	0.998	1.101
	Medicaid	0.0580	0.00717	65.3520	<.0001	1.060	1.045	1.075
	Private insurance	0.1473	0.00723	415.1300	<.0001	1.159	1.142	1.175
	No Charge	0.2657	0.0347	58.7074	<.0001	1.304	1.219	1.396
	Other	0.2771	0.0103	729.1063	<.0001	1.319	1.293	1.346
	Self-pay*							
Operation on record	Major operating room procedure on record	0.5046	0.00397	16181.006 9	<.0001	1.656	1.643	1.669

Table 11. (continue) PDI 10 Postoperative Sepsis Events (PPPD10), Logistic Regression (Bivariate analysis) for hospital characteristics

Hospital Characteristics								
Hospital bed size		Estimate	SE	Wald Chi-Square	P-value	OR	Wald 95% confidence limits for OR	
	Small	-0.4188	0.00394	11274.5867	<.0001	0.658	0.653	0.663
	Medium	-0.3239	0.00354	8391.6575	<.0001	0.723	0.718	0.728
	Large*							
Hospital location	Rural	-1.1054	0.00554	39758.3051	<.0001	0.331	0.328	0.335
	Urban nonteaching	-0.7577	0.00471	25914.4857	<.0001	0.469	0.464	0.473
	Urban teaching*							
Hospital region	Northeast	-0.1244	0.00458	738.2960	<.0001	0.883	0.875	0.891
	Midwest	-0.3318	0.00429	5975.8777	<.0001	0.718	0.712	0.724
	South	-0.2533	0.00374	4587.0104	<.0001	0.776	0.771	0.782
	West *							
Hospital ownership	Public	0.0624	0.00571	119.4138	<.0001	1.064	1.053	1.076
	Private, not- profit	0.0711	0.00447	252.8714	<.0001	1.074	1.064	1.083
	Private, investor-owned*							

Within the multivariate analysis, several variables remained independently associated with POS, while patient characteristics such as age and gender fell out of significance when controlling of other variables (p=0.5780, p=0.2823, respectively). Among racial categories, only Hispanic patients showed significantly lower odds of POS events (3.1%) (AOR = 0.969, 95% CI: 0.961 - 0.977, p < 0.0001) when compared to White patients and controlling for other variables. In contrast, Native American (AOR = 1.084, 95% CI: 1.054 - 1.114, p < 0.0001) and “Others” (AOR = 1.059, 95% CI: 1.046 - 1.072, p < 0.0001) patients had significantly higher odds of POS when compared to White patients and controlling for other variables (8.4% and 5.9% respectively). Black, and Asian/Pacific Islander patients did not exhibit significant differences in POS risk compared to White patients when controlling for other variables.

With regards to service line, all service lines remained significant ($p<.0001$) with Injury (AOR = 1.261, 95% CI: 1.241 - 1.281) and Surgical service lines (AOR = 1.314, 95% CI: 1.291 - 1.337) having higher odds (26.1% and 31.4%, respectively), and Maternal and Neonatal service lines having lower odds (AOR = 0.687, 95% CI: 0.682 - 0.692) when compared to Medical service lines and controlling for other variables (31.3%). Mental health/substance use service lines also exhibited lower odds (AOR = 0.787, 95% CI: 0.776 - 0.798) when compared to Medical services and controlling for other variables (21.3%).

Regarding patient payment sources which showed significant associations throughout the multivariate analysis. Patients with Medicaid as their payment source had significantly lower odds of POS (1.9%) (AOR = 0.981, 95% CI: 0.967 - 0.995, $p = 0.0073$), while those with Private insurance (AOR = 1.043, 95% CI: 1.028 - 1.059, $p < 0.0001$), No Charge (AOR = 1.356, 95% CI: 1.265 - 1.454, $p < 0.0001$), and Other payment sources (AOR = 1.073, 95% CI: 1.051 - 1.095, $p < 0.0001$) had significantly higher odds (4.3%, 35.6%, and 7.3%, respectively) compared to Self-pay patients and controlling for other variables. Patients with Medicare were found to not be significantly associated with POS events when compared to Self-pay patients and controlling for other variables.

Moreover, operation on record in hospital was also significantly associated with POS ($p<0.0001$), with major operating room procedure on record showing patients with Major operating room procedures on record having significantly higher odds (17.7%) of POS (AOR = 1.177, 95% CI: 1.160 - 1.194) when compared to patients without major operations on record and controlling for other variables.

With reference to hospital characteristics, Small and Medium-sized hospitals both have significantly lower odds of POS (28.2% and 21.4% respectively) compared to Large hospitals and controlling for other variables (AOR = 0.718, 95% CI: 0.712 - 0.723, and AOR = 0.786, 95% CI: 0.780 - 0.792, respectively, both $p < 0.0001$).

Hospital location, when compared to Urban Teaching hospitals, patients in Rural hospitals had significantly lower odds of POS (AOR = 0.364, 95% CI: 0.360 - 0.368, $p < 0.0001$) when controlling for other variables (63.3%). Patients in Urban nonteaching hospitals also had significantly lower odds (AOR = 0.520, 95% CI: 0.515 - 0.525, $p < 0.0001$) when compared to Urban teaching hospitals and controlling for other variables (48.0%).

Moreover, hospital region was a significant characteristic of POS when compared to the West region and controlling for other variables, the odds of POS were significantly lower in the Midwest region (AOR = 0.775, 95% CI: 0.768 – 0.782) and the South region (AOR = 0.802, 95% CI: 0.795 – 0.808), followed by the odds for the Northeast region (AOR = 0.824, 95% CI: 0.817 – 0.832) (all $p < 0.0001$) (22.5%, 19.8%, and 17.6%, respectively).

Hospital Ownership, on the other hand, showed that compared to Private, investor-owned hospitals and controlling for other variables, Private not-for-profit hospitals (AOR = 0.910, 95% CI: 0.902 - 0.919, $p < 0.0001$) demonstrated significantly lower odds of POS, as did Public hospitals (OR=0.979, 95% CI: 0.968 - 0.991) (both $p < 0.0001$) (9.0% and 2.1% respectively).

The logistic regression analyses conducted in this study provided valuable insights into the factors associated with POS. The bivariate analysis showed that patient characteristics such as gender, age, and race were significantly related to the occurrence of POS. Specifically, being female was associated with a slightly lower risk of POS, while increasing age and being Black, Hispanic, or Asian/Pacific Islander were associated with a slightly higher risk. However, patient characteristics such as age and gender did not retain significance when controlling for other variables. This implied that age and gender might indirectly influence POS through other factors. The same was observed amongst most race associations, as Black and Asian/Pacific Islander became insignificant predictors of POS events while an inverse relationship of association was noted amongst Hispanic, Native American and Others. This demonstrated that the relationship between these factors was implicated in the complexity of the PAE and may depend on the presence of other variables that modulate these associations.

Furthermore, the analysis revealed that service line was significantly associated with POS. Maternal and Neonatal service line had the lowest risk, while Surgical and Injury service lines had the highest risk. This is likely a reflection of the impact of heavy operational procedures in those types of services provided yet can provide directionally interventions tailored to specific service lines and be beneficial in reducing the risk. Moreover, operation on record remained a consistent factor in the likelihood of POS, emphasizing the need to attain certain attention to repeat patients.

The analysis of hospital characteristics demonstrated that both hospital bed size and location were significantly associated with POS. Smaller hospitals and rural locations were consistently associated with a lower risk, while urban teaching hospitals had a higher risk, further reflecting a potential concentration of operational services of higher risks in these areas and types. Additionally, hospital region and ownership type showed significant associations. These findings highlight the role of the healthcare infrastructure and organization in the occurrence of POS, emphasizing the need for targeted interventions and resource allocation to mitigate the risk.

The multivariate analysis confirmed the associations observed in the bivariate analysis, further affirming the significance of patient and hospital characteristics in analyzing the impact of independent variables on the occurrence of POS. Moreover, payment source, operation on record, were identified as additional variables independently associated with POS indicating the importance of comprehensive factors such as healthcare coverage and effective management of critical patients to reduce POS.

Collectively, the findings of this study underscore the multifactorial nature of POS and highlight the complex interplay between patient characteristics and healthcare system factors. Through which, underscoring the intricate interplay between various variables in the context of POS risk. The complexity of the model highlights the need to consider multiple factors when assessing the risk of POS to obtain a more accurate understanding of its determinants. The identified associations provide valuable insights for healthcare providers and policymakers to develop targeted strategies and interventions aimed at preventing and managing POS.

Table 12. PDI 10 Postoperative Sepsis Events (PPPD10), Logistic Regression (Multivariate analysis).

Variable		Estimate	SE	Wald test	P-value	Adjusted OR	Wald 95% Confidence Limits for IRR	
Intercept		-1.1956	0.00969	15223.4432	<.0001	0.303	-	-
Age		0.000133	0.000239	0.3095	0.5780	1.000	1.000	1.001
Sex	Female	0.00328	0.00305	1.1558	0.2823	1.003	0.997	1.009
	Male*			.	.	.		
Race	White*							
	Black	0.00668	0.00432	2.3928	0.1219	1.007	0.998	1.015
	Hispanic	-0.0318	0.00413	59.3682	<.0001	0.969	0.961	0.977
	Asian/Pacific Islander	0.00636	0.00742	0.7340	0.3916	1.006	0.992	1.021
	Native American	0.0802	0.0141	32.4814	<.0001	1.084	1.054	1.114
	Others	0.0573	0.00625	83.8824	<.0001	1.059	1.046	1.072
Service line	Maternal and Neonatal	-0.3752	0.00380	9764.0955	<.0001	0.687	0.682	0.692
	Mental health/substance use	-0.2396	0.00686	1221.0395	<.0001	0.787	0.776	0.798
	Injury	0.2318	0.00808	822.7288	<.0001	1.261	1.241	1.281

Variable		Estimate	SE	Wald test	P-value	Adjusted OR	Wald 95% Confidence Limits for IRR	
	Surgical	0.2728	0.00889	942.0917	<.0001	1.314	1.291	1.337
	Medical*							
Payment Source	Medicare	0.0301	0.0257	1.3687	0.2420	1.031	0.980	1.084
	Medicaid	-0.0197	0.00734	7.1986	0.0073	0.981	0.967	0.995
	Private insurance	0.0423	0.00744	32.3544	<.0001	1.043	1.028	1.059
	No Charge	0.3047	0.0354	74.1019	<.0001	1.356	1.265	1.454
	Other	0.0701	0.0105	44.5725	<.0001	1.073	1.051	1.095
	Self-pay*							
Operation on record	Major operating room procedure on record	0.1631	0.00728	501.9870	<.0001	1.177	1.160	1.194
Hospital bed size	Small	-0.3318	0.00404	6728.2117	<.0001	0.718	0.712	0.723
	Medium	-0.2408	0.00364	4379.8857	<.0001	0.786	0.780	0.792
	Large*							
Hospital location	Rural	-1.0109	0.00574	31018.6116	<.0001	0.364	0.360	0.368
	Urban nonteaching	-0.6532	0.00484	18213.8946	<.0001	0.520	0.515	0.525
	Urban teaching*							
Hospital region	Northeast	-0.1931	0.00481	1613.2327	<.0001	0.824	0.817	0.832
	Midwest	-0.2549	0.00460	3076.2645	<.0001	0.775	0.768	0.782
	South	-0.2210	0.00398	3077.9496	<.0001	0.802	0.795	0.808
	West *							
Hospital ownership	Public	-0.0209	0.00592	12.4474	0.0004	0.979	0.968	0.991
	Private, not- profit	-0.0940	0.00472	396.9995	<.0001	0.910	0.902	0.919
	Private, investor-owned*							

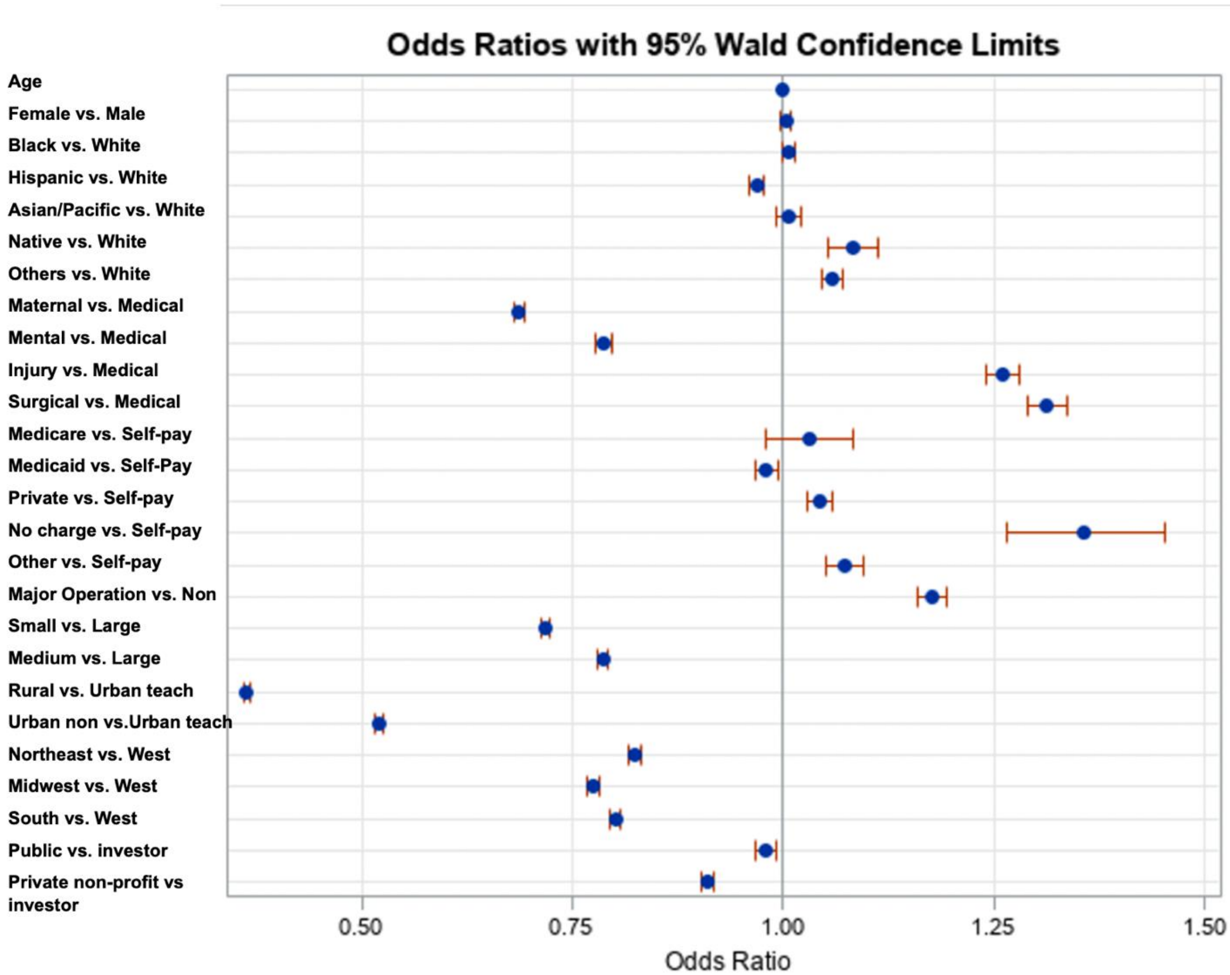

Figure 4. Independent variables Odds Ratio with 95% Wald Confidence Limits Associated with POS (multivariate).

CHAPTER 5: DISCUSSION, IMPLICATIONS & RECOMMENDATIONS, STRENGTHS & LIMITATIONS, FURTHER STUDY & CONCLUSION

DISCUSSION

This study focused on assessing the characteristics of AEs in pediatric patients in the inpatient hospital setting. The study utilized AHRQ's PDIs and analyzed the association of hospital and patient characteristics with these indicators at the patient level. The study specifically examined three PDIs: NQI 03, PDI 09 and PDI 10. The data used in the study was based on discharge data from the 2019 HCUP KID database, which provided the latest and most comprehensive healthcare information available for pediatric patients. The study employed a population-based retrospective cohort design to minimize selection bias and allowed for the utilization of logistic regression to examine associations between select patient and hospital characteristics with PAEs.

Furthermore, the study aimed to evaluate the validity of utilizing PDIs as a framework for understanding PAEs and designing targeted interventions. The findings of this analysis provide an overview designed to highlight the multifactorial nature of PAEs and emphasize the importance of considering patient demographics and hospital characteristics when assessing the risk of AEs. The study contributes to the existing literature by providing empirical evidence on the relationship between these factors and the occurrence of PAEs.

One significant finding of this study is was considering the role of gender in areas covered by the three PDIs utilized in this study. Gender, in fact, was found to perhaps play a lesser role in identifying avenues for practical applications such as QI measures, as gender was found to not be a significant predictor of the two operative PDIs (PDI 09 and PDI 10) when controlling for other variables. Apart from a minor 0.9% increased odds in NBSI when compared to males, gender was more likely to be associated as a bivariate predictor. This indicates that though gender is an integral part of screening, especially in the case for NBSI, much consideration needs to be attributed to it in relation to various confounding factors. Moreover, with MDR-GN monitoring being a part of infection control measures, gender like other pediatric factors could play a role in understanding and maneuvering around antibiotic resistance. As for operative medical functions previous research highlighted the vulnerability of males to PAE (Feyissa et al., 2020; Slonim et al., 2003; Tansuwannarat et al., 2022), the findings of this study call for further investigation, and possible case studies on what goes on in the wholistic view of operations to influence PAEs when gender is considered.

Age, according to this study, only played a significant role in PORF risk when controlled for other variables. It, nonetheless, echoed concerns for impact of this variable on operative pediatric functions. With the neonatal case, population age defines the patients and the observance of this population in all their variables draws attention to the complexity of neonatal cases and NBSI.

The interplay of racial categories was a striking finding of this study. Black patients were of significantly higher odds than White patients in NBSI but not significantly associated with the operative PDIs. In somewhat a similar fashion, Hispanic patients were significantly of higher odds than White patients in the operative PDIs, whereas Asian/Pacific Islander patients consistently showed higher odds than White patients across PDIs (insignificant in POS multivariate). Native American patients fluctuated across PDI with lower odds in NBSI and higher in the operative ones though showcasing a reversal between bivariate and multivariate analysis. Meanwhile, Other patients were of significantly higher odds than White patients when associated with PDIs. These inversed relationships could signify disparities among different racial groups, highlighting the possible impact of comorbidities and other physiological factors as the multivariate analysis further highlighted the complexities and interplay of these factors. More research is merited with regards to their role with regards to regional and demographic areas.

When taking in the perspective of a patient seeking regular medical services, and comparing the odds of PAEs to that view, the type of medical service provided was significantly associated with PAE in both direct and confounded ways. As Maternal and Neonatal services saw lower odds across the board, Surgical service lines carried significantly higher risks for the two operative PDIs, while showcasing a complex interplay with regards to NBSI. Reasonably, Mental Health/substance abuse was not associated with NBSI, it also logically came with significantly lower odds in the operative spheres. Intriguingly, the Injury service line showed significantly higher odds in one of the operative PDIs but otherwise did not show any association when controlling for other variables. These findings suggest that the complexity and invasiveness of surgical procedures may contribute to a higher risk of PORF and POS in pediatric patients, echoing findings of previous smaller scale research (Adams et al., 2021; Deans et al., 2020; Park et al., 2021). It is important to note that the service lines identified in this study portray differing levels of complexity and invasiveness, which could contribute to the observed differences in AE odds. Further research is needed to better understand the factors underlying these associations and to identify strategies for mitigating AEs in high-risk service lines, while also keeping in mind patient characteristics and records for pancaked risks.

As was mentioned in earlier studies (Smith et al., 2012), Medicaid did indeed play a significant role in the likelihood of experiencing some PAEs, and most notably, NBSI. Similar to the Smith et al., (2012) study, this study calls for further investigation into the complex web of significant factors at play with regards to the relationship between Medicaid and the operative PDIs. Nonetheless, because of this study, private insurance was highlighted as a payment source of concern when compared to Self-pay patients. This point of comparison was adopted in this study to emphasize the point of view of an independent patient as its perspective. This allows for research to view the variable in as less related values as possible, as opposed to the social and governmental connotations that are attached to Medicaid and Medicare, No Charge and Other. Overall, the alarm raised by private insurance' relationship to PAEs when taken into view alongside governmentally sponsored payment sources merits quality investigation and further study into the impact on hospitals due to the types of payment they accept, receive, or rely on. This could also be said with regards to "No charge", and "Other" patients and their significant impact on the risk of PDIs. Medicare on the other hand, showed no significant association to operative PDIs yet was associated with slower odds of NBSI.

A dire and urgent finding of this study has highlighted the presence of a major operation as significantly associated with higher odds of PAE across PDIs. These findings should render it of utmost importance to consider the need and urgency for added operative procedures with repeat patients, while accurately assessing the confounded risk of additional or extended operations on pediatric patients with a previous record.

Moreover, this study also observed the prevalence and complexity of sepsis in pediatric care as two of the PDIs examined addressed pediatric sepsis. The findings of this study urge healthcare providers to consider sepsis control bundles as a holistic measure during all stages of pediatric care. Further, this study encourages practitioners to consider various factors when designing applications for sepsis control, or CLABSI bundles.

Regarding hospital characteristics, small and medium sized hospitals consistently showed lower odds of PAE; rural also, and urban non-teaching hospitals, all also showed significantly lowers odds when compared to urban teaching hospitals. This reflects a clear observation that smaller, more rural hospitals are not central locations for major type surgeries and thus the most prominent PAEs. Nonetheless, this draws attention to the importance of addressing transportation difficulties and barriers to access to timely healthcare; a sister issue that hinders rural patients as well as inner city children from receiving adequate and timely care which could in turn exasperate comorbidities (Syed et al., 2013).

Hospital region, conversely, displayed significant associations with PDIs, with the Midwest and Northeast regions consistently showcasing significantly lower odds when compared to western hospitals. The South, on the other hand, had significantly higher odds of NBSI when controlling for other variables. This could reflect environmental contexts or deeper demographic and regional variances that make the South more suspectable to neonatal sepsis, warranting a deeper socio-geographic healthcare study.

Furthermore, hospital ownership was significantly associated with all PAEs with varying impacts reflecting on the odds of complications occurring in these types of hospitals. Further, highlighting the role of healthcare infrastructure, and the organizational resources available at facilities, that could influence the occurrence of AEs in pediatric patients. This study paves the way to the exchange of expertise and the establishment of blueprints for controlling settings in hospitals according to their types while observing population trends and their interaction with likewise various variables.

PBULIC HEALTH IMPLICATIONS & RECOMMENDATIONS

This study builds upon research utilizing the PDI framework and affirms their validity for understanding PAEs and designing interventions. The literature review provided valuable insights into the main points and factors contributing to PAEs, emphasizing the vulnerability of pediatric patients to AEs including factors such as medication errors. Further instances were reflected on the impact of coding systems on analyzing AEs, and the effectiveness of using PDIs to measure outcomes.

The findings of this study align with the research in supporting the validity of utilizing PDIs in understanding and addressing PAEs. The associations between patient characteristics, and hospital characteristics with AEs reinforce the need for targeted interventions to enhance pediatric patient safety. By targeting specific patient demographics, service lines, payment sources, and hospital characteristics, healthcare providers and policymakers can develop strategies to prevent and manage adverse events more effectively.

Some public health implications for enhancing pediatric patient safety and reducing the occurrence of AEs in healthcare settings could be based on the associations discovered as follows:

1) Address Health Disparities: The findings underscore the need to address disparities in PAE risk related to race and payment source, focusing on improving access to healthcare, addressing genetic and reducing social determinants of health while promoting equitable care (AHRQ, 2021)
2) Risk Stratification: Healthcare providers should use patient characteristics to stratify patients based on their risk for PAEs and implement tailored interventions (Dom Dera J.,

2019). These further, should be prioritized in the exploration of future research as their confounding nature seems to permeate throughout the analysis.

3) Improve Infection Control Measures: Hospitals, especially those performing major operating room procedures, should enhance infection control measures tailored to specific service lines and bed sizes. Teaching hospitals could benefit from more attention drawn to the vulnerability of their patients.
4) Consider Regional Variation: Public health efforts should be directed toward regions with higher PAEs risk, understanding that regional differences may be related to infection control practices, healthcare infrastructure, demographics, as well as environmental or sociocultural contexts exasperating certain PAEs.
5) Investigate Hospital Ownership: Further research is needed to understand the factors influencing PAEs in different hospital ownership types. Guiding policy and quality improvement initiatives, should be a clear understanding of budgeting systems, organizational objectives, and the impact of cash flow on hospital operations.

Public Health Recommendations

Based on the findings of this study, some public health recommendations could be made to help better understand and mitigate the risk of PAEs for QI purposes. Some of these findings can be summarized as follows:

1. Targeted Interventions: The findings highlight the need for targeted interventions aimed at specific patient populations and healthcare settings. Structured strategies have been touted for their task of seeking to change the social and environmental contexts that yield and perpetuate social and health inequalities (Brown et al., 2019). In this context, these structured strategies should focus on addressing the identified risk factors associated with AEs, such as

patients undergoing major surgical procedures, those of certain economic background, and those at an increased risk for AEs. By this, interventions can be built upon robust evaluation designs and measures—derived from a broad range of disciplines and capable of harnessing big data across sectors—to address the evidence gap in our understanding of the impact and reproducibility of structural interventions developed to reduce health disparities (Brown et al., 2019). Interventions could include improved monitoring protocols, standardized care pathways, and robust QI initiatives that focus on patient safety and AE prevention. These QI initiatives, in turn, that were successfully developed in one community might be adapted, scaled up, and transferred to another setting of critical importance (Brown et al., 2019).

2. Education and Training: It is crucial to invest in continued research, and comprehensive education and training programs for medical researcher and healthcare providers working in pediatric care (HealthManagement.org, 2023). This should encompass topics such as patient safety, medication administration, infection prevention, and communication skills. Furthermore, emphasizing the necessity of specialist skills capable of addressing the unique challenges and vulnerabilities of pediatric patients can help improve awareness and promote best practices.

3. Research and Surveillance: Continued research is needed to further understand the underlying mechanisms and causal relationships between patient and hospital characteristics and AEs. Longitudinal studies, implementation research, and the use of advanced data analytics can provide valuable insights into the effectiveness of interventions and guide evidence-based decision-making. Further studies utilizing the HCUP KID database and the PDI framework can offer additional findings against the backdrop of its extensive reach.

STRENGTHS & LIMITATIONS

One strength of this study is the use of a large and comprehensive database, the HCUP KID 2019, which provides a robust, recent, sample size and allows for extensive analysis. The use of logistic regression analysis also enabled the examination of multiple factors simultaneously and the identification of independent associations.

However, it is important to acknowledge the limitations of this study. The analysis is based on administrative data, which may limit the possible variables that can be observed, eliminating the organic nature of PAE events, as there may be other unmeasured confounding factors that could influence the associations. Also, though the study employed the most recent data available, the study focused on a specific timeframe and may not capture the most recent trends and advancements in pediatric patient safety, especially considering the COVID-19 pandemic. Furthermore, the associations identified in our analysis do not establish causality, and further research is needed to explore the underlying mechanisms and validate our findings.

RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the findings of this study, there are several recommendations for future research. First, longitudinal studies using KID could be conducted to explore the temporal relationships between the identified factors and PAEs. This would provide a clearer understanding of causality and potential mechanisms.

Second, qualitative research methods, such as interviews or focus groups, could be employed to gain insights into the experiences and perspectives of patients, caregivers, and healthcare providers regarding PAEs. This could inform the development of tailored interventions and strategies.

Further investigation into the relationships present with patient outcomes could also reveal urgency and severity of certain PDIs and help in the design of targeted interventions based on persistent need.

Lastly, research is needed to explore the effectiveness of specific interventions aimed at reducing PAEs and specifically NQI 03, PDI 09 and PDI 10, all with their own certain traits and needs. More specifically, research into the impact of cash flow on hospital operations, and in turn, PAEs in warranted. Randomized controlled trials or quasi-experimental designs could be utilized to evaluate the impact of targeted interventions on patient outcomes.

CONCLUSION

Through a comprehensive literature review and logistic regression analyses, the study has identified significant associations between patient and hospital characteristics as well as patient outcome and the occurrence of three most prevalent PDIs. These findings contribute to the existing body of knowledge on pediatric patient safety and provide a foundation for targeted interventions and QI initiatives. Further, this study confirms that PAE and the specific PDIs identified do not happen in a vacuum, but rather are in a complex web of variables that warrant further investigation.

This study further confirms the validity of the PDI framework with statistical analysis to capture relevant associations in a large database specified for kids. It underscores the importance of standardized reporting, data integration, and the use of PDIs to measure outcomes and identify areas for improvement. By leveraging these tools, healthcare providers and policymakers can develop evidence-based strategies to enhance pediatric patient safety.

REFERENCES

Agarwal-Harding, K. J., von Allmen, D., & Deans, K. J. (2019). Adverse events in pediatric surgery: a review of the literature and analysis of incident reports from a surgical safety registry.. Pediatric Surgery International.

Agency for Healthcare Research and Quality. (n.d.). Disparities in healthcare - 2021 National Healthcare Quality and ... https://www.ncbi.nlm.nih.gov/books/NBK578532/

Agency for Healthcare Research and Quality: A Profile. Content last reviewed July 2022. Agency for Healthcare Research and Quality, Rockville, MD.https://www.ahrq.gov/cpi/about/profile/index.html

Agency for Healthcare Research and Quality. (2020, July). Quality Indicators Software Instructions and Data Dictionary SAS QI® v2020. Rockville. Retrieved from chrome extension: //efaidnbmnnnibpcajpcglclefindmkaj/https://qualityindicators.ahrq.gov/Downloads/Software/SAS/v2020/Software_Inst_SASQI_v2020_July_2020.pdf.

Bierlaire, S., Danhaive, O., Carkeek, K., & Piersigilli, F. (2021). How to minimize central line–associated bloodstream infections in a neonatal intensive care unit: a quality improvement intervention based on a retrospective analysis and the adoption of an evidence-based bundle. European Journal of Pediatrics, 180(2), 449–460. https://doi.org/10.1007/s00431-020-03844-9

Brown AF, Ma GX, Miranda J, Eng E, Castille D, Brockie T, Jones P, Airhihenbuwa CO, Farhat T, Zhu L, Trinh-Shevrin C. Structural Interventions to Reduce and Eliminate Health Disparities. Am J Public Health. 2019 Jan;109(S1):S72-S78. doi: 10.2105/AJPH.2018.304844. PMID: 30699019; PMCID: PMC6356131.

Canet, Jaumea; Gallart, Lluísb. Postoperative respiratory failure: pathogenesis, prediction, and prevention. Current Opinion in Critical Care 20(1):p 56-62, February 2014. | DOI: 10.1097/MCC.0000000000000045

Centers for Disease Control and Prevention (CDC). (2021). CDC/NHSN surveillance definitions for specific types of infections. Retrieved from https://www.cdc.gov/nhsn/pdfs/pscmanual/17pscnosinfdef_current.pdf

Cheon EC, Palac HL, Paik KH, Hajduk J, De Oliveira GS, Jagannathan N, Suresh S. Unplanned, Postoperative Intubation in Pediatric Surgical Patients: Development and Validation of a Multivariable Prediction Model. Anesthesiology. (2016 Nov);125(5):914-928. doi: 10.1097/ALN.0000000000001343. PMID: 27617685

Classen DC et al.(2011). 'Global Trigger Tool' Shows That Adverse Events In Hospitals May Be Ten Times Greater Than Previously Measured.' Health Affairs 30(4):581–589.

Davenport MC, Domínguez PA, Ferreira JP, Kannemann AL, Paganini A, Torres FA. Measuring adverse events in pediatric inpatients with the Global Trigger Tool. Arch Argent Pediatr. 2017 Aug 1;115(4):357-363. English, Spanish. doi: 10.5546/aap.2017.eng.357. PMID: 28737864.

Dom Dera J. Risk Stratification: A Two-Step Process for Identifying Your Sickest Patients. Fam Pract Manag. 2019 May/Jun;26(3):21-26. PMID: 31083868.

Duff P, et al. (2020). Microbial etiology and antibiotic resistance of neonatal bloodstream infections in a United States hospital. Journal of Perinatology, 40(10), 1533-1541. doi: 10.1038/s41372-020-00781-2

Eric C. Cheon, Hannah L. Palac, Kristine H. Paik, John Hajduk, Gildasio S. De Oliveira, Narasimhan Jagannathan, Santhanam Suresh; Unplanned, Postoperative Intubation in Pediatric Surgical Patients: Development and Validation of a Multivariable Prediction Model. Anesthesiology 2016; 125:914–928
doi: https://doi.org/10.1097/ALN.0000000000001343

Falcone, M. L., Van Stee, S. K., Tokac, U., & Fish, A. F. (2022). Adverse Event Reporting Priorities: An Integrative Review. *Journal of patient safety*, *18*(4), e727–e740. https://doi.org/10.1097/PTS.0000000000000945

Feyissa, D., Kebede, B., Zewudie, A., & Mamo, Y. (2020). Medication Error and Its Contributing Factors Among Pediatric Patients Diagnosed with Infectious Diseases Admitted to Jimma University Medical Center, Southwest Ethiopia: Prospective Observational Study. *Integrated pharmacy research & practice*, *9*, 147–153. https://doi.org/10.2147/IPRP.S264941

Flannery DD, Chiotos K, Gerber JS, Puopolo KM. Neonatal multidrug-resistant gram-negative infection: epidemiology, mechanisms of resistance, and management. Pediatr Res. 2022 Jan;91(2):380-391. doi: 10.1038/s41390-021-01745-7. Epub 2021 Oct 1. PMID: 34599280; PMCID: PMC8819496.

Garrouste-Orgeas, M., Philippart, F., Bruel, C., Max, A., Lau, N., & Misset, B. (2012). Overview of medical errors and adverse events. *Annals of intensive care*, *2*(1), 2. https://doi.org/10.1186/2110-5820-2-2

Grober, E. D., & Bohnen, J. M. (2005). Defining medical error. *Canadian journal of surgery. Journal canadien de chirurgie*, *48*(1), 39–44.

Gupta M, et al. (2021). The effectiveness of a sepsis prevention bundle in reducing neonatal bloodstream infections in a large hospital system in the United States. Infection Control & Hospital Epidemiology, 42(2), 224-230. doi: 10.1017/ice.2020.361

Harding, A. (2004). Study finds US paediatric medical errors kill 4500 children a year. *BMJ : British Medical Journal, 328*(7454), 1458. https://doi.org/10.1136/bmj.328.7454.1458-b

Halvorson, E. E., Thurtle, D. P., Easter, A., Lovato, J., & Stockwell, D. (2022). Disparities in Adverse Event Reporting for Hospitalized Children. *Journal of patient safety*, *18*(6), e928–e933. https://doi.org/10.1097/PTS.0000000000001049

HealthManagement.org. (2023, October 27). *The importance of continuous education in Healthcare*. HealthManagement. https://healthmanagement.org/c/healthmanagement/issuearticle/the-importance-of-continuous-education-in-healthcare

HCUP Databases. Healthcare Cost and Utilization Project (HCUP). February 2022. Agency for Healthcare Research and Quality, Rockville, MD. www.hcup-us.ahrq.gov/kidoverview.jsp.

ICD-10-CM/PCS Resources. Healthcare Cost and Utilization Project (HCUP). April 2022. Agency for Healthcare Research and Quality, Rockville, MD. www.hcup-us.ahrq.gov/datainnovations/icd10_resources.jsp

Institute of Medicine (US) Committee on Quality of Health Care in America, Kohn, L. T.,

Corrigan, J. M., & Donaldson, M. S. (Eds.). (2000). *To Err is Human: Building a Safer Health System*. National Academies Press (US).

Jarry, J. (2021, August 27). *Medical error is not the third leading cause of death*. Office for Science and Society. Retrieved December 27, 2022, from https://www.mcgill.ca/oss/article/critical-thinking-health/medical-error-not-third-leading-cause-death

Kohn, L. T., Corrigan, J. M., & Donaldson, M. S. (Eds.). (2000). To err is human: building a safer health system. National Academies Press.

Makary, M. A., & Daniel, M. (2016). Medical error-the third leading cause of death in the US. *BMJ : British Medical Journal (Online)*, *353*https://doi.org/10.1136/bmj.i2139

Mangus, C. W., & Mahajan, P. (2019). Common Medical Errors in Pediatric Emergency Medicine. *Clinical Pediatric Emergency Medicine*, *20*(3). https://doi.org/https://doi.org/10.1016/j.cpem.2019.100714

Miller MR et al.(2011) Patient Safety Indicators for Pediatrics: Technical Specifications and Resource Manual (Version 5). AHRQ Publication No.: 11(12)-0054.

Milliren, C. E., Bailey, G., Graham, D. A., & Ozonoff, A. (2022). Relationships Between Pediatric Safety Indicators Across a National Sample of Pediatric Hospitals: Dispelling the Myth of the "Safest" Hospital. *Journal of patient safety*, *18*(4), e741–e746. https://doi.org/10.1097/PTS.0000000000000938

Mueller, B. U., Neuspiel, D. R., Fisher, E. R. S., & COUNCIL ON QUALITY IMPROVEMENT AND PATIENT SAFETY, COMMITTEE ON HOSPITAL CARE (2019). Principles of Pediatric Patient Safety: Reducing Harm Due to Medical Care. *Pediatrics*, *143*(2), e20183649. https://doi.org/10.1542/peds.2018-3649

National Quality Forum (NQF). Safe Practices for Better Healthcare–2010 Update: A Consensus Report. Washington, DC: NQF; 2010.

Nizamuddin SL, Gupta A, Latif U, et al. A Predictive Model for Pediatric Postoperative Respiratory Failure: A National Inpatient Sample Study. Journal of Intensive Care Medicine. 2021;36(7):798-807. doi:10.1177/0885066620928272

NORC of the University of Chicago. (2021, May 21). *Surveys of Trust in the U.S. Health Care System*. Retrieved December 27, 2022, from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.norc.org/PDFs/ABIM%20Foundation/20210520_NORC_ABIM_Foundation_Trust%20in%20Healthcare_Part%201.pdf

Rhee, D., Zhang, Y., Papandria, D., Ortega, G., & Abdullah, F. (2012). Agency for Healthcare Research and Quality pediatric indicators as a quality metric for surgery in children: do they predict adverse outcomes?. *Journal of pediatric surgery*, *47*(1), 107–111. https://doi.org/10.1016/j.jpedsurg.2011.10.025

Sharek, P. J., Horbar, J. D., Mason, W., Bisarya, H., Thurm, C. W., Suresh, G., ... & Classen, D. (2010). Adverse events in the neonatal intensive care unit: development, testing and findings of a NICU-focused trigger tool to identify harm in North American NICUs. Pediatrics, 126(4), 919-928.

Singer, M., Deutschman, C. S., Seymour, C. W., Shankar-Hari, M., Annane, D., Bauer, M., ... & Angus, D. C. (2016). The third international consensus definitions for sepsis and septic shock (Sepsis-3). Jama, 315(8), 801-810.

Slonim, A. D., LaFleur, B. J., Ahmed, W., & Joseph, J. G. (2003). Hospital-reported medical errors in children. *Pediatrics*, *111*(3), 617–621. https://doi.org/10.1542/peds.111.3.617

Smith, R. B., Dynan, L., Fairbrother, G., Chabi, G., & Simpson, L. (2012, August 1). Medicaid, hospital financial stress, and the incidence of adverse medical events for children. Health Services Research, 47(4), 1621. https://doi.org/10.1111/j.1475-6773.2012.01385.x

Stephanie J. Schrag, Monica M. Farley, Susan Petit, Arthur Reingold, Emily J. Weston, Tracy Pondo, Jennifer Hudson Jain, Ruth Lynfield; Epidemiology of Invasive Early-Onset Neonatal Sepsis, 2005 to 2014. Pediatrics December 2016; 138 (6): e20162013. 10.1542/peds.2016-2013

Stockwell, D. C., Landrigan, C. P., Toomey, S. L., Loren, S. S., Jang, J., Quinn, J. A., Ashrafzadeh, S., Wang, M. J., Wu, M., Sharek, P. J., Classen, D. C., Srivastava, R., Parry, G.,

Schuster, M. A., & GAPPS Study Group (2018). Adverse Events in Hospitalized Pediatric Patients. *Pediatrics*, *142*(2), e20173360. https://doi.org/10.1542/peds.2017-3360

Stoll BJ, Hansen NI, Sánchez PJ, et al. Epidemiology of neonatal blood stream infections in the United States, 2006-2015. The Journal of the Pediatric Infectious Diseases Society. 2020;9(2):143-151. doi: 10.1093/jpids/piz005.

Stoll, BJ., Hansen, N., Fanaroff, A. A., Wright, L. L., Carlo, W. A., Ehrenkranz, R. A., ... & Poindexter, B. B. (2011). Late-onset sepsis in very low birth weight neonates: the experience of the NICHD Neonatal Research Network. Pediatrics, 129(2), e580-e590. doi: 10.1542/peds.2011-0072

Stoll BJ, Puopolo KM, Hansen NI, Sánchez PJ, Bell EF, Carlo WA, Cotten CM, D'Angio CT, Kazzi SNJ, Poindexter BB, Van Meurs KP, Hale EC, Collins MV, Das A, Baker CJ, Wyckoff MH, Yoder BA, Watterberg KL, Walsh MC, Devaskar U, Laptook AR, Sokol GM, Schrag SJ, Higgins RD; Eunice Kennedy Shriver National Institute of Child Health and Human Development Neonatal Research Network. Early-Onset Neonatal Sepsis 2015 to 2017, the Rise of Escherichia coli, and the Need for Novel Prevention Strategies. JAMA Pediatr. 2020 Jul 1;174(7):e200593. doi: 10.1001/jamapediatrics.2020.0593. Epub 2020 Jul 6. Erratum in: JAMA Pediatr. 2021 Feb 1;175(2):212. PMID: 32364598; PMCID: PMC7199167.

Syed ST, Gerber BS, Sharp LK. Traveling towards disease: transportation barriers to health care access. J Community Health. 2013 Oct;38(5):976-93. doi: 10.1007/s10900-013-9681-1. PMID: 23543372; PMCID: PMC4265215.

Tansuwannarat P, Vichiensanth P, Sivarak O, Tongpoo A, Promrungsri P, Sriapha C, Wananukul W, Trakulsrichai S. Characteristics and Consequences of Medication Errors in Pediatric Patients Reported to Ramathibodi Poison Center: A 10-Year Retrospective Study. *Ther Clin Risk Manag*. 2022;18:669-681 https://doi.org/10.2147/TCRM.S363638

Tessema B, Lippmann N, Knüpfer M, Sack U, König B. Antibiotic Resistance Patterns of Bacterial Isolates from Neonatal Sepsis Patients at University Hospital of Leipzig, Germany. Antibiotics (Basel). 2021 Mar 19;10(3):323. doi: 10.3390/antibiotics10030323. PMID: 33808878; PMCID: PMC8003699.

Thakkar, R. K., Weiss, S. L., Fitzgerald, J. C., Keele, L., Thomas, N. J., Nadkarni, V. M., Muszynski, J. A., & Hall, M. W. (2019). Risk Factors for Mortality in Pediatric Postsurgical versus Medical Severe Sepsis. Journal of Surgical Research, 242, 100–110.

World Health Organization. (2014). Companion Handbook to the WHO Guidelines for the Programmatic Management of Drug-Resistant Tuberculosis. Geneva: World Health Organization. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK247402/

World Health Organization. (2020). WHO draft guidelines for adverse event reporting and learning systems: From information to action. https://www.who.int/publications/i/item/WHO-EMP-HIS-2020.

Xiaofeng Wang, Michael W. Kattan, Cohort Studies: Design, Analysis, and Reporting, Chest, Volume 158, Issue 1, Supplement, 2020, Pages S72-S78, ISSN 0012-3692, https://doi.org/10.1016/j.chest.2020.03.014.

Vachirapuranon, S., Vijarnsorn, C., Kanjanauthai, S., Tocharoenchok, T., Durongpisitkul, K., Chanthong, P., ... & Phachiyanukul, A. (2022). Major infections following pediatric cardiac surgery pre-and post-CLABSI bundle implementation. PeerJ, 10, e14279.

Vera, I., & Henriquez, A. (2019). A Review of Zero-Inflated Negative Binomial Regression Models for Count Data. Journal of Statistical Distributions and Applications, 6(1), 5. https://doi.org/10.1186/s40488-019-0092-4

APPENDIX

RESEARCH QUESTIONS AND RESEARCH HYPOTHESES

NQI 03	Status	
Research Hypothesis	Rejected	Supported
H1A. Hospital region is significantly associated with NQI 03 when controlling for other risk factors		X
H2A. Teaching/nonteaching status of the hospital is significantly associated with NQI 03 when controlling for other risk factors.		X
H3A. Rurality of the hospital is significantly associated with NQI 03 when controlling for other risk factors.		X
H4A. Control ownership of the hospital is significantly associated with NQI 03 when controlling for other risk factors.		X
H5A. Hospital bed size is significantly associated with NQI 03 when controlling for other risk factors.		X
H1B. Gender is significantly associated with NQI 03 when controlling for other risk factors.		X
H2B. Payor status is significantly associated with NQI 03 when controlling for other risk factors.		X
H3B. Race is significantly associated with NQI 03 when controlling for other risk factors.		X
H4B. Previous major operation status is significantly associated with NQI 03 when controlling for other risk factors.		X
H5B. Service line is significantly associated with NQI 03 when controlling for other risk factors (except for Mental Health/ Subtance abuse)		

		X
H6B. Age is significantly associated with NQI 03 when controlling for other risk factors.	N/A	

PDI 09	Status	
Research Hypothesis	Rejected	Supported
H1A.2. Hospital region is significantly associated with PDI 09 when controlling for other risk factors.		X
H2A.2. Teaching/nonteaching status of the hospital is significantly associated with PDI 09 when controlling for other risk factors.		X
H3A.2. Rurality of the hospital is significantly associated with PDI 09 when controlling for other risk factors.		X
H4A.2. Control ownership of the hospital is significantly associated with PDI 09 when controlling for other risk factors.		X
H5A.2. Hospital bed size is significantly associated with PDI 09 when controlling for other risk factors.		X
H1B.2. Gender is significantly associated with PDI 09 when controlling for other risk factors	X	
H2B.2. Payor status (except for Medicare and No Charge) is significantly associated with PDI 09 when controlling for other risk factors.		X
H3B.2. Race (except Black and Other) is significantly associated with PDI 09 when controlling for other risk factors.		X
H4B.2. Previous major operation status is significantly associated with PDI 09 when controlling for other risk factors.		X
H5B.2. Service line (except Injury) is significantly associated with PDI 09 when controlling for other risk factors.		X

H6B.2. Age is significantly associated with PDI 09 when controlling for other risk factors.		

PDI 10	Status	
Research Hypothesis	Rejected	Supported
H1A.2. Hospital region is significantly associated with PDI 10 when controlling for other risk factors.		X
H2A.2. Teaching/nonteaching status of the hospital is significantly associated with PDI 10 when controlling for other risk factors.		X
H3A.2. Rurality of the hospital is significantly associated with PDI 10 when controlling for other risk factors.		X
H4A.2. Control ownership of the hospital is significantly associated with PDI 10 when controlling for other risk factors.		X
H5A.2. Hospital bed size is significantly associated with PDI 10 when controlling for other risk factors.		X
H1B.2. Gender is significantly associated with PDI 10 when controlling for other risk factors	X	
H2B.2. Payor status (except for Medicare) is significantly associated with PDI 10 when controlling for other risk factors.		X
H3B.2. Race (except Black and Asian/Pacific Islander) is significantly associated with PDI 10 when controlling for other risk factors.		X
H4B.2. Previous major operation status is significantly associated with PDI 10 when controlling for other risk factors.		X
H5B.2. Service line is significantly associated with PDI 10 when controlling for other risk factors.		X
H6B.2. Age is significantly associated with PDI 10 when controlling for other risk factors.		

	X	