Hospital-Acquired Pressure Injuries in a Medical ICU

Retrospective Chart Review & Data Analysis

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Abstract

Background Intensive care unit (ICU) patients are susceptible to developing hospital acquired pressure injuries (HAPIs) which are associated with prolonged hospitalization, morbidity, and mortality. Determination of HAPI causes is difficult and not well elucidated.

Aim This quality improvement (QI) project aimed to identify risk factors for HAPIs in a medical ICU (MICU).

Methods A chart review of 20 patients that developed HAPIs during August/September 2021 and February/March 2022 in a single MICU. The data gathered included patient demographics, medical history, bloodwork, medical interventions, Braden/RASS scores, MICU days, and MICU staffing/patient census. SPSS software analyzed the data and correlations were meaningful at the significant ($p < .05$), marginal ($p < .10$) or trend level ($p < .20$).

Results Females had significantly fewer days in the MICU prior to their HAPI (correlation coefficient (r) (20 patients) = -.48, $p = .031$). Patients with elevated creatinine at hospital admission had fewer days in the MICU prior to their HAPI ($r(20) = -.37$, $p = .112$). Patients with higher Braden scores and higher RASS scores at HAPI diagnosis had fewer days in the MICU prior to their HAPI ($r(20) = -.36$, $p = .123$; $r(20) = -.42$, $p = .068$, respectively). Certified nurse assistant (CNA) coverage at night was significantly associated with more days in the MICU prior to HAPIs ($r(20) = .53$, $p = .016$), and dayshift CNA coverage was trending ($r(20) = .31$, $p = .190$).

Discussion Many studies found male gender associated with HAPIs. Not the case in this study. Trends for HAPI development have been seen in this project warranting further large-scale studies.

Keywords: hospital acquired pressure injuries, HAPI, medical intensive care unit, MICU

Hospital-Acquired Pressure Injuries in a Medical ICU

Hospital-acquired pressure injuries (HAPIs) are a significant cause of morbidity and mortality, and represent a substantial burden for healthcare systems worldwide (Goodman et al., 2018; Labeau et al., 2020). By definition, a pressure injury (PI) is localized damage to the skin and underlying soft tissue from pressure or pressure combined with shear, usually over bony prominences or related to medical devices or other devices (National Pressure Injury Advisory Panel [NPIAP] et al., 2019). Pressure is the force exerted perpendicular to the skin surface, whereas shear is the force exerted parallel to the tissue (National Database of Nursing Quality Indicators [NDNQI], 2021). Tissue tolerance is the ability of the skin and supporting structures to endure pressure without complications (Tschannen & Anderson, 2020). Pressure injuries are classified according to the severity and level of tissue injury, which include: 1) Stage I: Non-blanchable erythema of intact skin; 2) Stage II: Partial-thickness skin loss with exposed dermis; 3) Stage III: Full thickness skin loss; 4) Stage IV: Full-thickness skin and tissue loss; 5) Unstageable: Obscured full-thickness skin and tissue loss; 6) Deep tissue: Persistent non-blanchable deep red, maroon, or purple discoloration (NDNQI, 2021; NPIAP et al., 2019). All stages of PIs are prone to complications, which include cellulitis, osteomyelitis, necrotizing fasciitis, and septicemia (Aboud & Manna, 2021).

Hospital-acquired PIs are associated with severe pain and disability, psychological distress, increased risk of nosocomial infections, prolonged hospitalization (average 5-10 days per PI), and a 25% increased risk of mortality (Labeau et al., 2020; Lin et al., 2020; Mordiffi et al., 2021). Furthermore, HAPIs can result in chronic wounds, and are responsible for about 60,000 deaths annually (Bauer et al., 2016). Hospital-acquired PIs are one of many hospital-acquired conditions (HAC) monitored by the Centers for Medicare and Medicaid Services (CMS), and despite the wide implementation of prevention strategies, HAPIs are the only HAC increasing in prevalence, with a 6% increase from 2014 to 2017 (Agency for Healthcare Research and Quality [AHRQ], 2019). Moreover, the care and treatment for HAPIs stage III and IV is non-reimbursable; therefore, hospitals face the full financial burden of these harms (Li et al., 2020). The incremental cost of treating HAPIs is approximately $10,708 per patient, and costs are estimated to exceed $26.8 billion annually in the United States (Padula & Delarmente, 2019).

Furthermore, the cost of care for chronic PIs is estimated at $22 billion annually (Nussbaum et al., 2018).

Patients in the intensive care unit (ICU) are particularly susceptible to developing HAPIs due to a myriad of risk factors, including comorbidities, limited mobility, hemodynamic instability, poor tissue perfusion and oxygenation, vasopressor agents, and invasive medical devices (Barakat-Johnson et al., 2019; Jackson et al., 2019; Soodmand et al., 2019). Advances in medicine and technology have led to a substantial ICU population of geriatric patients who have an increased risk of developing HAPIs (Flaatten et al., 2017). A systematic review of HAPIs among ICU patients showed a prevalence of 16.9–23.8% and an incidence rate of 10.0–25.9% (Chaboyer et al., 2017). Similarly, the DecubICUs study involving 1,117 ICUs (13,254 patients) in 90 countries showed a prevalence of 26.6% (6,747) HAPIs and 59.2% (3,997) were ICU-acquired (Labeau et al., 2020).

Hospital acquired PIs remain a persistent problem in a 15-bed medical ICU (MICU) at Pacific Northwest Hospital (PNWH), despite the implementation of PI prevention strategies. Currently, the MICU has higher rates of HAPIs compared to the cardiac ICU, as well as all other units at PNWH. Upon review, the MICU leadership team does not know why patients are getting HAPIs or which patients are at greater risk (Appendix A). Though there is a plethora of clinical data available via electronic health records (EHRs) the exploration of the data on patients with HAPIs has not been executed. Therefore, determining which patients are at greater risk of developing a PI in the MICU has been identified as a critical topic for a quality improvement (QI) project.

Available Knowledge

Not all HAPIs are preventable even with high-quality nursing care and provision of preventative measures (Black et al., 2011; Wound, Ostomy, and Continence Nurses [WOCN] Society, 2019). Recently, a retrospective study evaluated preventative interventions performed on 165 patients who developed a HAPI while in critical care between 2012 and 2014, and found that 67 HAPIs (41%) were unavoidable (Pittman et al., 2019). That said, accurate risk identification should be the first step in PI prevention and evidence suggests that current PI predictive models fail to consider the magnitude of PI risk factors that have been identified over the past few years (Tschannen & Anderson, 2020). Therefore,

evidence-based PI prevention interventions remain elusive.

Factors affecting pressure, such as mobility, sensory perception, and medical equipment have been the focus of recent PI research, as well as extrinsic factors impacting tissue tolerance, such as friction, shear, and moisture, and intrinsic factors, such as age, body mass index (BMI), nutrition, oxygenation, tissue perfusion, and medication (i.e., vasopressors) (Tschannen & Anderson, 2020). A recent retrospective chart review of 143 ICU patients with Covid-19 requiring intubation and proning showed that 68 patients (47.6%) developed a facial PI (cheek 84%; ears 50%), and the average duration of proning for patients who developed a PI was significantly longer compared to patients who did not develop a PI (6.79 days vs. 3.64 days, $P < .001$) (Shearer et al., 2021). Furthermore, the intensity and duration of pressure and the susceptibility of the tissue (tissue tolerance) determine the level of risk for PI formation (Tschannen & Anderson, 2020). The DecubICUs study discovered that HAPIs were mostly found on the sacrum (37%) and heels (19.5%), and were primarily associated with intrinsic factors impacting tissue tolerance, rather than extrinsic factors (Labeau et al., 2021). Specifically, the risk factors identified in this study included older age, male gender, low BMIs, emergency surgery, higher Simplified Acute Physiology Score (SAPS) II (estimates ICU mortality), Braden score < 19 (predicts PI risk), ICU stay > 3 days, mechanical ventilation, renal replacement therapy, and comorbidities, such as immunodeficiency and chronic obstructive pulmonary disease (Labeau et al., 2021). Similarly, higher rates of HAPIs have been found in patients with chronic conditions including pulmonary, cardiovascular, renal, and liver disease, diabetes, and malignant tumors (Bly et al., 2016; Delmore et al., 2015; Liu et al., 2012; Nassaji et al., 2014; O'brien et al., 2015; Rao et al., 2016).

A literature review of research on HAPIs from 2006 through 2016 identified various PI risk factors, including reduced mobility, hypotension, poor oxygenation, fever, incontinence, low/high BMI, malnutrition, low albumin, high creatinine, high blood urea nitrogen (BUN), low hemoglobin (Hgb), elevated glucose, mechanical ventilation, vasodilators, vasopressors, corticosteroids, sedation, low nurse-to-patient ratio, longer ICU stay, high SAPS II score, low Richmond Agitation-Sedation Scale (RASS) score, and low Braden score (Aydin et al., 2015; Cox & Roche, 2015; Barakat-Johnson et al., 2019;

Jackson et al., 2019; Soodmand et al., 2019; Tschannen & Anderson, 2020). The Braden scale evaluates a patient's risk of developing a HAPI by scoring sensory perception, moisture, activity, mobility, nutrition, and friction/shear; however, critically ill patients have additional PI risk factors that are not considered in the Braden scale (PI risk score: high (< 12), moderate (13-15), mild (16-17), average (>18) (Dweekat et al., 2023). A recent systematic review and meta-analysis (60 studies; 49,326 patients) found that the Braden scale has a moderate predictive validity for PI risk assessment, and it is more suitable to identify PI risk for age < 60 years, and the Caucasian population (Huang et al., 2021).

The analysis of large-scale datasets from EHRs is one method to develop a more accurate, robust model of PI risk factors, including the recognition of variables most predictive of PIs (Tschannen & Anderson, 2020). The implementation of EHRs and digitalization of the ICU has led to the creation of huge datasets and a rapid growth of health data science, which is the field of study dedicated to the principled extraction of knowledge from "Big Data" (Sanchez-Pinto et al., 2018). The term Big Data in healthcare refers to the analysis of datasets that collect a vast amount of data of different origins (i.e., monitors and clinical observation) and format (i.e., continuous variables), resulting in datasets too large for traditional data-processing systems (Bates et al., 2014; Celi et al., 2013). The analysis of ICU datasets allows for new knowledge with consequential improvements in clinical practice (Carra et al., 2020).

The ICU presents a particularly compelling case for data analysis, as many aspects of critical illness and the value of treatments and interventions in the ICU remain characterized by a high-degree of uncertainty and scarce clinical evidence (Ghassemi et al., 2015; Sanchez-Pinto et al., 2018). Therefore, new insights into critical illness, treatments, and interventions in the ICU through the integration of data collected at the bedside are desperately needed (Citerio et al., 2015; Olson et al., 2015). Despite the promising start of Big Data analysis in medical research with an increasing number of peer-reviewed research articles, very limited applications have been used in the ICU (Carra et al., 2020).

Collectively, the literature review provided insight into the magnitude of risk factors associated with HAPIs and revealed an emerging need for more accurate PI risk identification. The analysis of ICU datasets from EHRs is one method of achieving a more robust model of PI risk factors. The use of Big

Data has potential to revolutionize ICU care, allowing for new knowledge and subsequent improvements in the management of ICU patients.

Rationale

The Model for Improvement (MFI) framework guided this QI project. The MFI has been an effective tool for quality initiatives in healthcare improvement science literature and has aided organizations in restructuring QI projects, resulting in advancement in clinical outcomes, cost reduction, and superior efficiency (Crowl et al., 2015; Picarillo, 2018). The MFI advocates structuring a QI project by setting an aim statement (what are we trying to accomplish), defining measures (how will we know if a change is an improvement), and selecting changes worthy of testing (what changes can we make that will result in improvement) (Picarillo, 2018, p. 930).

To combat HAPIs, it is critical to identify risk factors contributing to PIs, as complex problems are rarely resolved without understanding underlying causes (Black, 2019). A system-level change addresses the root causes of a problem, as opposed to a surface-level change, which only addresses symptoms (Barakat-Johnson et al., 2020). Conclusions from a chart review and data analysis can be used to identify areas of opportunity and promote a system-level change (Black, 2019). Early recognition of patients at risk for developing a PI is an integral part of any PI prevention strategy (Gupta et al., 2020).

Specific aims

Two aims of this project include: 1) Identify risk factors for developing a HAPI in the MICU; and 2) Compare risks for developing a HAPI between two time periods: August/September 2021, when HAPIs increased in the MICU during the peak of the Delta variant of SARS-CoV-2, the virus that causes Covid-19, and February/March 2022, during low Covid-19 census.

Methods

Context

The PNWH is a 378-bed level II trauma center that serves nine counties in Southern Oregon. The MICU is a 15-bed unit that provides critical care for pediatric and adult trauma patients, severe brain injuries, strokes, multiorgan failure, and postoperative care for neurosurgical patients. The MICU is

staffed with 67 core nurses and 10 certified nursing assistants (CNAs). Staffing for a 12-hour shift requires a minimum of eight bedside nurses (2:1 or 1:1 nurse-to-patient ratio), one charge nurse, and one CNA. Medical treatment is guided by eight intensivists, including five Doctors of Medicine (MDs), one Doctor of Osteopathic Medicine (DO), one Physician Assistant (PA), and one Acute Care Nurse Practitioner with a Doctor of Nursing Practice (ACNP-DNP). The multidisciplinary team also includes respiratory therapists (RTs), occupational and physical therapists (OTs/PTs), dieticians, and WOCNs.

This QI project was designed to examine associations with HAPIs in the MICU. Stakeholders for this project include the MICU nurse manager and supervisor, and two clinical nurse specialists with a Doctor of Nursing Practice (CNS-DNP). The nurse manager and CNSs are responsible for approving, overseeing, and supporting the implementation of QI projects.

Intervention

A retrospective chart review of patients that developed a HAPI in the MICU during the following months:1) August 1, 2021, to September 30, 2021; and 2) February 1, 2022, to March 30, 2022. The data was documented in an Excel spreadsheet, and included the following variables: 1) Patient demographics; 2) Medical history; 3) Bloodwork; 4) Inpatient/MICU days; 5) Medical interventions; 6) Braden/RASS scores; 7) HAPI location/stage; and 8) MICU staffing/patient census.

The following demographic data was collected: 1) Age; 2) Gender; 3) Ethnicity; and 4) Residence. The following medical history was collected: 1) Admitting diagnosis; 2) Discharge diagnoses; 3) Surgery during admission; 4) HAPI stage/location; 5) Diabetes; 6) HgbA1c; 7) Baseline mobility; 8) Cognitive disabilities; 9) Pulmonary disease; 10) Chronic and/or acute heart failure; 11) Ejection fraction; 12) Chronic or acute atrial fibrillation; 13) Chronic kidney disease and/or acute kidney injury; 14) Shock; 15) BMI, height, and weight. The following bloodwork was collected at hospital admission and at HAPI diagnosis: 1) White blood cells; 2) Red blood cells; 3) Hgb; 4) Creatinine; 5) BUN; 6) Glucose; and 7) Albumin. Other bloodwork included: 1) Covid-19; 2) Phosphorus (low/high); 3) Lactic acid (peak); and 4) Brain natriuretic peptide. Other data collected prior to HAPI included: 1) Total inpatient days; 2) Total MICU days; 3) Dates in the MICU; and 4) If transferred, from what hospital/unit. The following

interventions were collected prior to HAPI: 1) Vasodilators; 2) Vasopressors; 3) Sedation; 4) Corticosteroids; 5) Paralytic infusion; 6) Mechanical ventilation; 7) Diet; 8) OT/PT; and 9) Prone positioning. The following PI risk/sedation scores were collected: 1) Braden scale (lowest score and score at HAPI diagnosis; and 2) RASS score (at HAPI diagnosis). The following MICU data was collected: 1) Patient census; 2) Travel nurse-to-staff nurse ratio; 3) Nurse-and CNA-to-patient ratios.

Measures

The primary outcome measure identified risk factors for HAPIs in the MICU. The secondary outcome measure examined if patients were at greater risk for HAPIs in August/September 2021, during the peak of the Delta variant of SARS-CoV-2, or in February/March 2022, during low Covid-19 census. Process measures included patients with HAPIs and Covid-19, and nurse- and CNA-to-patient ratios. These process measures were chosen to assess if Covid-19 increased the risk for HAPIs and to assess how nurse- and CNA-to-patient ratio impacted HAPI risk. The balancing measures included the burden on the scheduling analyst to provide retrospective MICU staffing/patient census data, the time-consuming data culling, and the cost of a statistician. The data was collected, documented, and rechecked by two persons to ensure completeness and accuracy. The data was inputted twice and checked for errors.

Analysis

The Statistical Package for Social Sciences (SPSS) software was used to analyze the data. The analysis of the outcome and process measures was performed using descriptive statistics with Pearson bivariate correlations and simple T-tests. All the variables were standardized as z-scores to determine if there were outliers, and a score that lies 3.29 standard deviations (SD) from a sample mean was considered a univariate outlier. The dependent variable was the number of days a patient was in the MICU prior to their HAPI diagnosis, and the independent variables included medical history, bloodwork, medical interventions, RASS and Braden scores, and nurse- and CNA-to-patient ratios. To examine linearity, scatterplots (Appendix B) were analyzed prior to assessing bivariate correlations. Due to the small sample ($n = 20$), point estimates (correlations) were interpreted as potentially meaningful at the significant ($p < .05$), marginal ($p < .10$) or trend level ($p < .20$) (Appendix C). Fewer days in the MICU

prior to a HAPI diagnosis indicates an increased risk for developing a HAPI.

Ethical considerations

This QI project was submitted to PNWH and Oregon Health and Science University Institutional Review Boards and approved.

Results

The sample consisted of 20 patients that developed a HAPI in the MICU, 13 patients in August/September 2021 and seven patients in February/March 2022. These 20 patients consisted of eight women and 12 men; the mean age was 62.3 (35 – 85), the mean BMI was 30.62 (20.2 – 50.0), and 13 were Covid-19 positive. Eighteen patients were in shock, requiring vasopressors, and 18 were sedated, and on the ventilator. Therefore, vasopressor and ventilator days significantly correlated with MICU days prior to patients' HAPI diagnosis ($r(20) = -.826$, $p = < .001$; ($r(20) = -.902$, $p = < .001$, respectively). Thirteen patients had one HAPI, three patients had two HAPIs, three patients had three HAPIs, and one patient had four HAPIs, for a total of 32 HAPIs. Of these, 50% were located on the sacrum or buttocks, 31.25% on the face or ear, 12.5% on the extremities, and 6.25% on the back. The HAPIs were documented as stage II (15.6%), unstageable (34.4%), and deep tissue (50%). Eleven patients died, 10 patients from Covid pneumonia and one patient from complications following a trauma.

Outcome Measures

The primary outcome measures revealed that gender significantly correlated with days in the MICU prior to HAPI diagnosis, with females shown to have significantly fewer days in the MICU before their HAPI diagnosis ($r(20) = -.48$, $p = .031$) (Female mean days = 7.25, SD = 3.69; Male mean days = 12.17, SD 5.08) ($t(18) = 2.35$, $p = .031$) (Appendix D). In other words, being female was a potential risk factor for developing a HAPI. Patients with elevated creatinine levels at hospital admission had fewer days in the MICU prior to their HAPI diagnosis ($r(20) = -.37$, $p = .112$); therefore, in this study an elevated creatinine level was a risk factor for developing a HAPI. However, data checks indicated a potential bivariate outlier for this analysis, so results should be interpreted with caution. Patients with higher Braden scores (estimated lower PI risk) at HAPI diagnosis had fewer days in the MICU prior to

their HAPI diagnosis ($r(20) = -.36$, $p = .123$). Similarly, individuals with higher RASS scores (lighter sedation) at HAPI diagnosis had fewer days in the MICU prior to their HAPI diagnosis ($r(20) = -.42$, $p = .068$). Thus, a higher RASS and Braden score were risk factors for a HAPI.

The secondary outcome measure examined whether MICU days prior to HAPI diagnosis differed for patients in the MICU during August/September 2021compared to patients in the MICU during February/March 2022. Results indicated that there was no significant difference in days spent in the MICU prior to HAPI diagnosis during August/September 2021 (Mean days = 10.38, SD = 4.79) and February/March 2022 (Mean days = 9.86, SD = 6.04), ($t(18) = .22$, $p = .416$) (Appendix E).

The first process measure revealed that Covid-19 was not an independent risk factor for developing a HAPI ($r(20) = .24$, $p = .308$); though proning patients likely contributed to PIs on the face and ear (Bourkas et al., 2023). The second process measure demonstrated that a higher nurse-to-patient ratio was associated with more days in the MICU prior to patients' HAPI diagnosis; however, the results were not significant, marginal, or trending (Nurse day coverage: $r(20) = .28$, $p = .234$; Nurse night coverage: ($r(20) = .16$, $p = .512$). In contrast, a higher CNA-to-patient ratio during the day, while not significant, shows a potential trend ($r(20) = .31$, $p = .190$), and a higher CNA-to-patient ratio at night was significantly associated with delayed HAPI diagnosis ($r(20) = .53$, $p = .016$). Thus, increased CNA coverage was a protective factor that led to more days in the MICU prior to HAPI diagnosis.

Discussion

Summary

The findings provide initial, exploratory evidence of the risk factors for developing a HAPI in the MICU (variables that reduced the time it took for patients to develop a HAPI), as well as protective factors preventing a HAPI (variables that increased the time it took to develop a HAPI). To our knowledge, this is the first study that identified HAPI risk factors by analyzing the time it took for patients in the MICU to develop a HAPI and the first study to compare HAPI risk factors during the peak of the Delta variant of SARS-CoV-2 and low Covid-19 census. The most robust findings included nurse and CNA coverage, especially CNA coverage. Patients in the MICU during a time when there was more

CNA coverage had significantly more days in the MICU before developing a HAPI. Though not significant, creatinine, the only correlation for bloodwork trending, is a potential variable of interest. Unexpected findings included the increased risk for HAPIs in females and in patients with higher RASS and Braden scores at HAPI diagnosis. These unexpected findings may reflect better nursing/CNA care given to sicker male patients with low RASS and Braden Scale scores; thus, reducing their HAPI risk.

Interpretation

Gender

Consistent with our findings, a prospective comparative study of 286 surgical patients from 1996 through 1998 showed 117 patients developed a HAPI and female gender was a significant risk factor ($p < 0.001$) (Lindgren et al., 2005). Similarly, another prospective comparative study of 149 patients hospitalized for respiratory failure from December 2003 through May 2004 showed 38 patients developed a HAPI and females were at increased risk, though findings were not significant ($p = 0.379$) (Hatanaka et al., 2008). In contrast, a retrospective chart review and data analysis of variables related to HAPIs in 175 Korean hospitals (53,923 patients) from April 2017 through June 2017 showed that HAPIs were more common in males (Kim et al., 2022). Similarly, the DecubICUs study, a worldwide, one-day point-prevalence study of 13,254 patients in 1,117 ICUs revealed 3,997 ICU-acquired HAPIs and males were at increased risk (odds ratio (OR) [95% confidence interval (CI)] = 1.21 [1.08-1.36]) (Labeau et al., 2021). Additionally, a systematic review found 15 studies that included gender in multivariable modelling, and four studies showed a relationship between gender and PIs, with three studies identifying males at increased risk (Coleman et al., 2013). However, only one study focused on PIs in a MICU and two studies focused on PIs in long-term care facilities. The MICU study was a prospective comparative study of 698 patients admitted to a MICU from April 2001 through December 2004, and results showed 121 patients developed a HAPI and male gender was a significant risk factor ($p = 0.015$) (Compton et al., 2013).

Interestingly, 11 of the 15 studies in Coleman et al.'s (2013) systematic review found no association between gender and HAPIs. Similarly, a retrospective cohort analysis of EHR data of 12,566 patients admitted to a Mayo Clinic hospital ICU from January 2007 through December 2007 showed 416

patients developed stage II-IV HAPIs and there was no significant difference in HAPI risk based on gender ($p = 0.984$) (Tescher et al., 2012). More recently, a retrospective chart review and data analysis on 286 patients in a cardiac ICU in 2010, showed 47 patients developed a HAPI, and gender was not statistically significant ($p = .641$) (Shen et al., 2015). Another retrospective chart review and data analysis of 76 patients with HAPIs in a MICU from 2010 to 2012 showed no significant difference in HAPI risk based on gender (Smit et al., 2016). Similarly, a retrospective cohort analysis of EHR data of 242,745 patients from 15 hospitals from 2009 to 2010 showed 6,506 patients developed a HAPI and there was no significant difference in HAPI risk based on gender ($p = 0.427$) (Gardiner et al., 2016). Overall, contradicting results were shown for gender as a risk factor for developing a HAPI.

Creatinine

Our finding that elevated creatinine was a risk factor for HAPIs has some support in the literature. A retrospective chart review and analysis on surgical ICU patients at Yale New Haven Hospital in 2007 identified 25 patients that developed a stage II-IV HAPI, and creatinine > 3 mg/dL was found to be a significant independent risk factor (OR [95%]: 3.7 [1.2–9.3], $p < 0.019$) (Frankel et al., 2007). Similarly, a retrospective chart review and analysis of 849 surgical patients from November 2008 through December 2009 revealed 100 patients developed a HAPI and creatinine > 2.1 mg/dL was a significant independent risk factor ($p < 0.001$) (Corniello et al., 2016). In contrast, a four-year adverse event database (2003–2006) was derived from US military hospitals and a retrospective chart review and data analysis showed 333 patients developed a HAPI with a mean elevated creatinine of 1.6 mg/dL, which was not significantly associated with HAPIs ($p < 0.10$) (Raju et al., 2015).

Braden Score

The literature suggests that low Braden scores are associated with HAPIs, which is the opposite of our findings (Tschannen & Anderson, 2020). The DecubICUs study found that patients with a Braden score < 19 were at increased risk for HAPIs (Braden scores: 15-18: OR [95%]: 2.91 [1.81–4.68]; 13-14: OR [95% CI] 5.23 [3.25-8.42]; 10-12: OR [95% CI]: 6.52 [4.07–10.44]; < 9: OR [95% CI] 9.72 [CI 6.01-10.44]) (Labeau et al., 2021). Additionally, a retrospective cohort analysis of EHR data of 7,132 patients

with a HAPI in a Portuguese hospital during 2012 showed patients were at increased risk of HAPIs with Braden scores < 16 (OR [95% CI] 7.30 [5.39-9.88]) (Sardo et al., 2016). However, Hatanaka et al.'s (2008) comparative study revealed that none of the six Braden scale risk factors were associated with HAPIs; therefore, Braden scores were shown to have almost no ability to predict HAPIs. In contrast, Smit et al.'s (2016) retrospective chart review and data analysis showed low Braden scores were predictive of HAPIs; however, there was no significant difference in HAPI stage and Braden scores on admission (p = 0.07) or at HAPI diagnosis (p = 0.141).

RASS Score

The literature suggests that low RASS scores are associated with HAPIs, which is the opposite of our findings (Tschannen & Anderson, 2020). A recent retrospective review of 104 patients admitted to an ICU showed 13 patients developed a HAPI and RASS scores were lower in patients with HAPIs (p = .0001) even after adjustment for confounders (OR [95%CI]: 0.14 [0.03–0.58], p = .006); therefore, deeper sedation was a strong, highly accurate predictor of HAPIs (Sasabe et al., 2022). In contrast, a retrospective case-control study of 3,050 patients admitted to an ICU in Australia from January 2019 through December 2020, showed 75 patients developed a medical device (MD) HAPI and 14 patients developed a non-MD HAPI, and low RASS scores were not significantly associated with MD or non-MD HAPIs (OR [95%CI]: 0.44 [0.05 - 4.05], p = 0.47) (Weber et al., 2022).

Staffing: Nurse & CNA

Consistent with our findings, several studies have shown that higher nurse- and CNA-to-patient ratios reduce the risk of HAPIs (Tschannen & Anderson, 2020). However, some studies report mixed and non-significant findings, as well as counterintuitive findings. A systematic review of 12 studies from 2004 to 2012 showed mixed results for nurse staffing in relation to HAPIs, and only one study included CNA staffing (Stalpers et al., 2015). One ICU study demonstrated that higher CNA and nurse hours were significantly associated with fewer HAPIs (p < 0.10) (Goode et al., 2011). Similarly, higher nurse staffing was associated with lower rates of HAPIs (p < 0.05) in a retrospective data analysis of patients with HAPIs in 51 ICUs (Stone et al., 2007). Additionally, a descriptive cross-sectional study comparing the

databases of the American Hospital Association (AHA) and Office of State-wide Health Planning and Development (OSHPD) for 372 California hospitals showed that higher nurse hours per adjusted patient day had significantly lower rates of HAPIs (AHA: $p = .001$; OSHPD: $p = .002$) (Jiang et al., 2006). Comparably, a New Zealand study reported a significant increase in HAPIs across all hospital units following a 36% decrease in nursing hours between 1993 and 2000 (McCloskey & Diers, 2005). More recently, Kim et al.'s (2022) retrospective chart review and data analysis showed that increased nurse- and CNA-to-patient ratios significantly reduced HAPIs (Hazard ratio (HR) = 0.20, $p < .001$, HR = 0.12, $p < .001$, respectively). In contrast, a study of 124 Florida hospitals between 1996 and 2004 found that higher nursing hours were associated with higher incidences of HAPIs ($r = .996$, $p = .05$) (Unruh & Zhang, 2012). Similarly, another study from 2002 to 2006 showed higher nursing hours were significantly associated with increased HAPI prevalence in 65 non-ICUs ($r = .928$, $p = .004$) (Bolton et al., 2007). However, the same study sample from 2002 to 2004 showed no association between nursing hours and HAPIs (Donaldson et al., 2005).

Five studies in different countries (Australia, Belgium, England, Sweden, US) found no associations between nurse hours and HAPIs (Gunningberg et al., 2012; Kendall-Gallagher & Blegen, 2009; Shuldham et al., 2009; Twigg et al., 2011; Van den Heede et al., 2009). More recently, a retrospective chart review and analysis of nurse staffing and HAPIs in three hospitals from October 2010 through March 2012 showed that nurse-to-patient ratios were not significantly related to HAPIs (Bae et al., 2014). Similarly, a cross-sectional study in Germany used two large national databases to assess the association between nurse staffing and HAPI incidence in 710 hospitals in 2010 (716,281 patients) and 672 hospitals in 2012 (757,665 patients) and found no association between nurse-to-patient ratios and HAPI incidence (Schneider et al., 2016). Collectively, contradicting results were shown for measures of nurse and CNA staffing in relation to HAPIs; thus, further studies are needed to provide a clearer explanation of the relationship between HAPIs and nurse- and CNA-to-patient ratios.

Limitations

The primary limitation was the small sample size for this study, which limited the ability to detect

significant associations. Although several correlations were large and pointed to medium or large effect sizes, the small sample limits the ability to discuss these findings with confidence. In addition, this study involved a relatively large number of bivariate tests. Although these variables were chosen *a priori*, increasing the number of tests can also increase the potential for random or meaningless effects.

Conclusion

The etiology of HAPIs is multifaceted and not well elucidated. This study identifies several variables associated with HAPIs, and highlights the importance of adequate nurse- and CNA-to-patient ratios to prevent HAPIs. These findings warrant further exploration of the risk factors for a HAPI.

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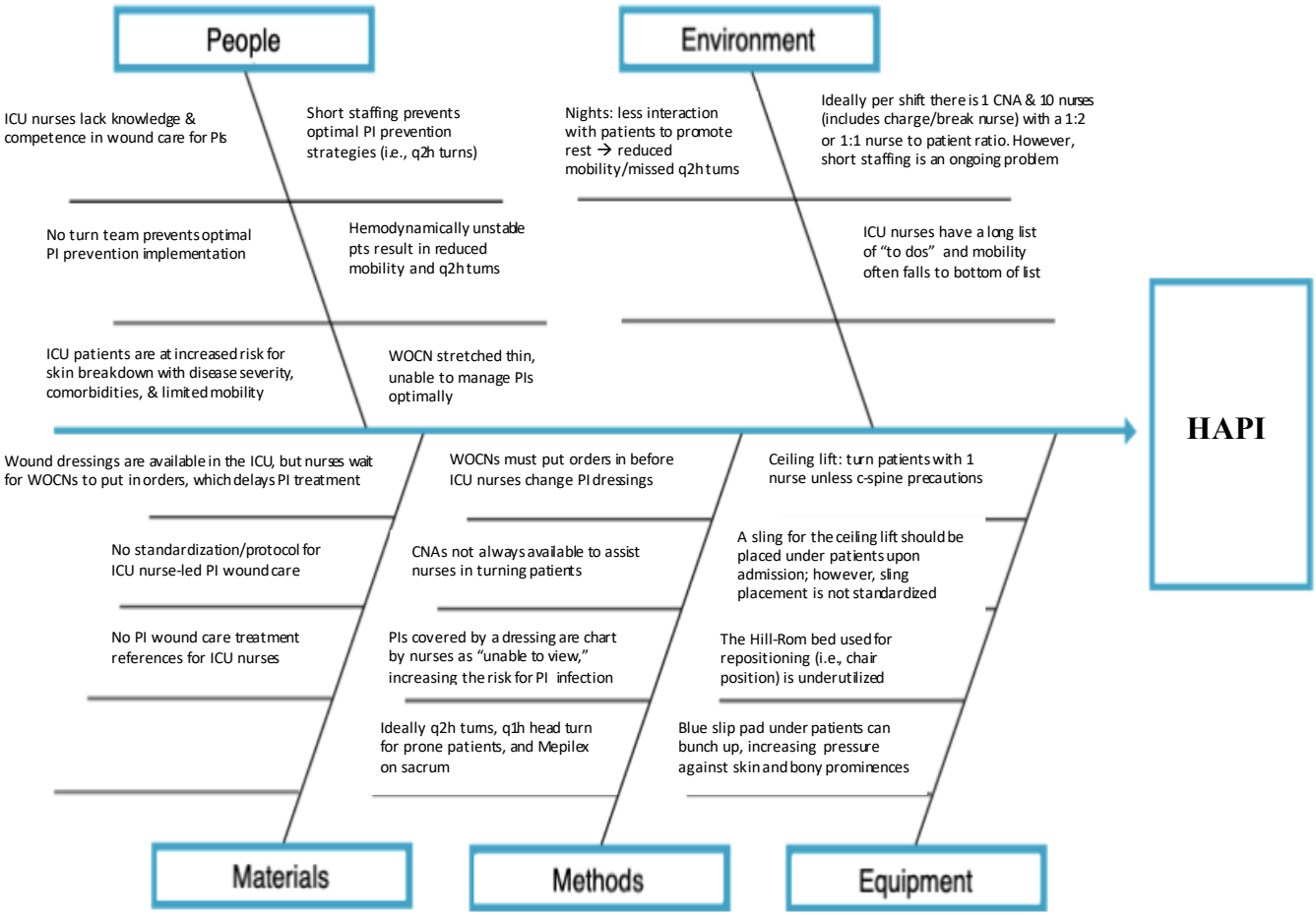
Appendix A

Cause and Effect Diagram

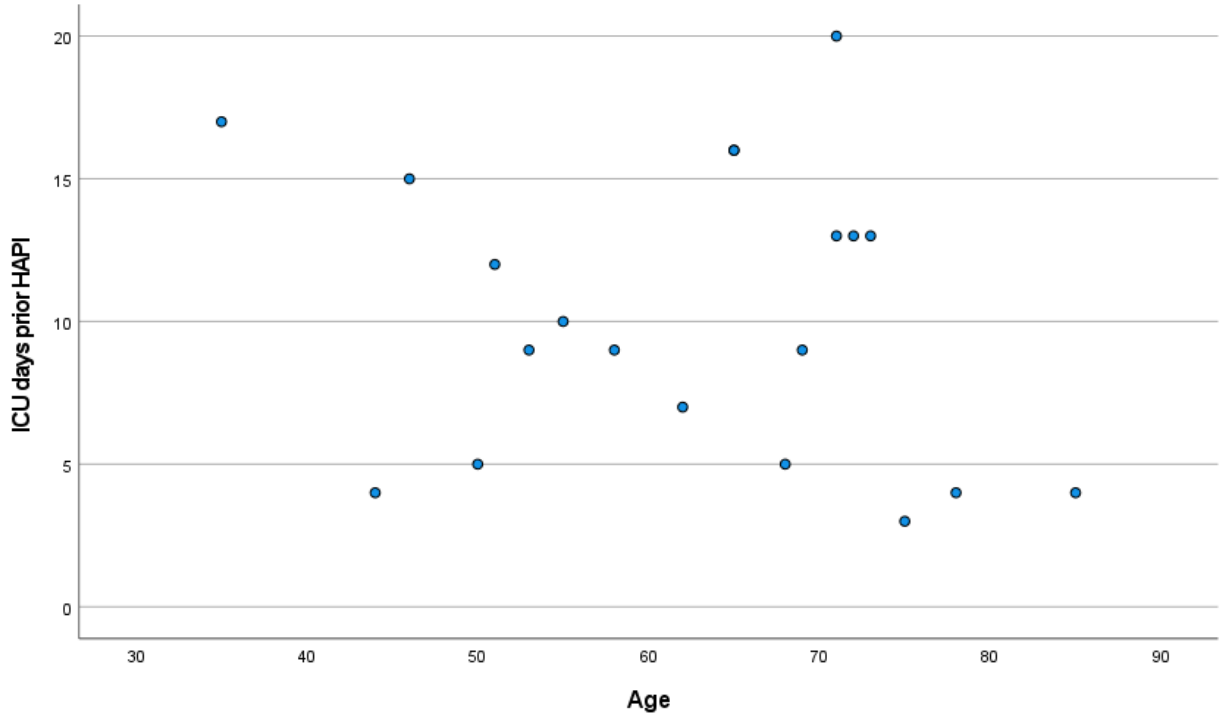
Team: Rachel Codd, DNP-student MICU Leadership

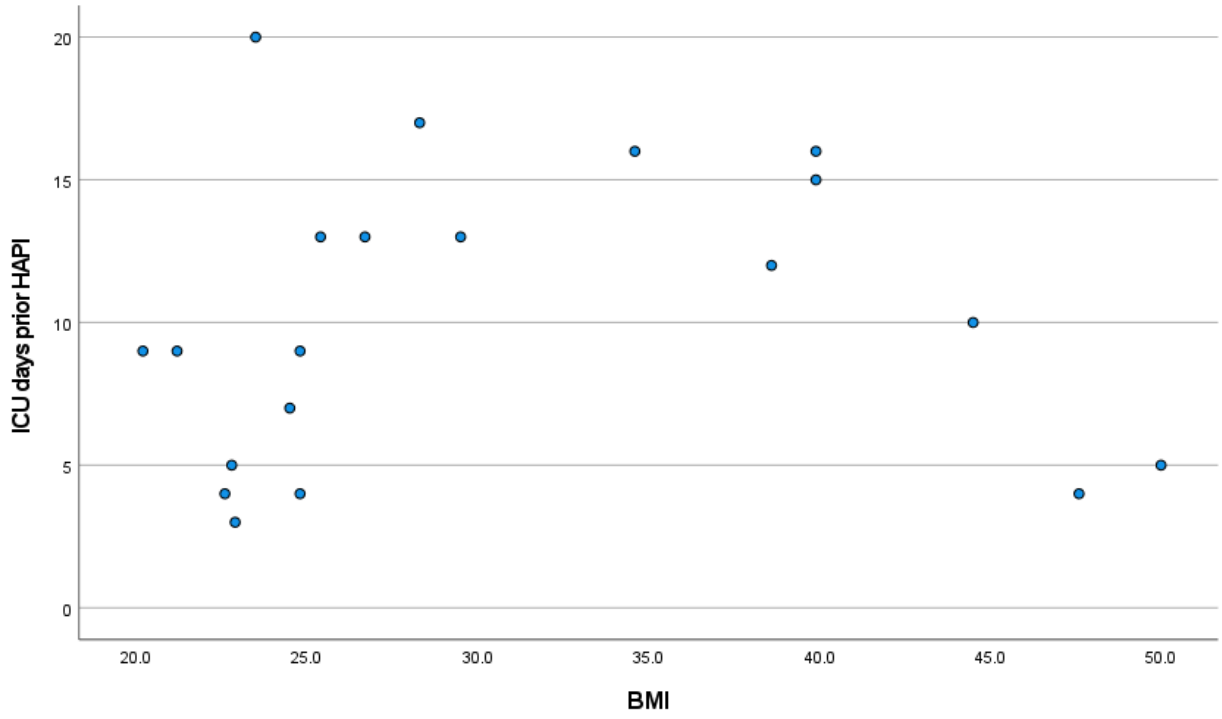
Project: Retrospective chart review/data analysis of HAPIs in a MICU

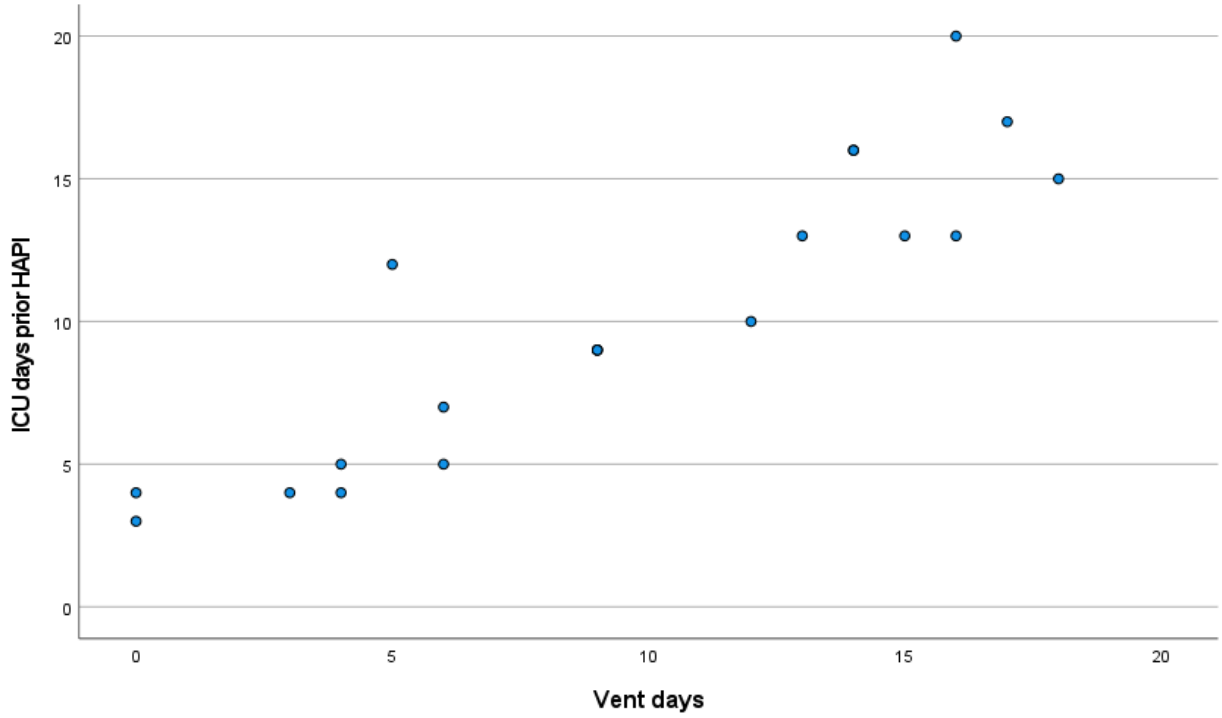


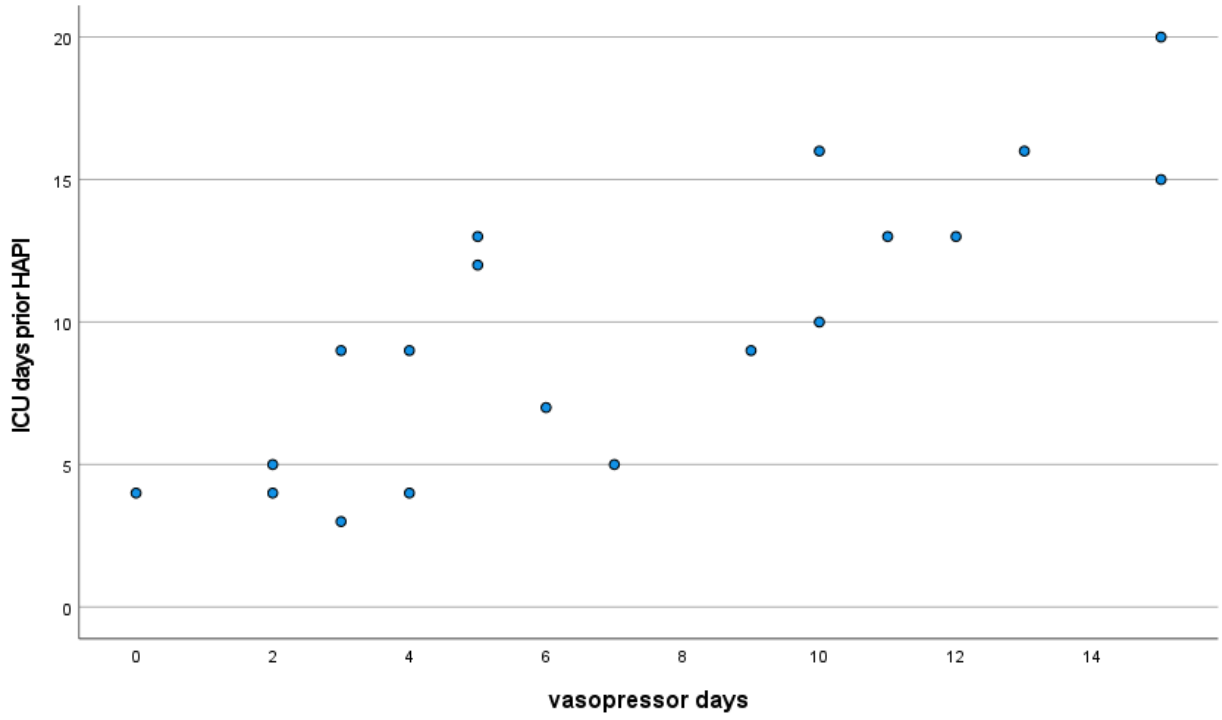
Appendix B

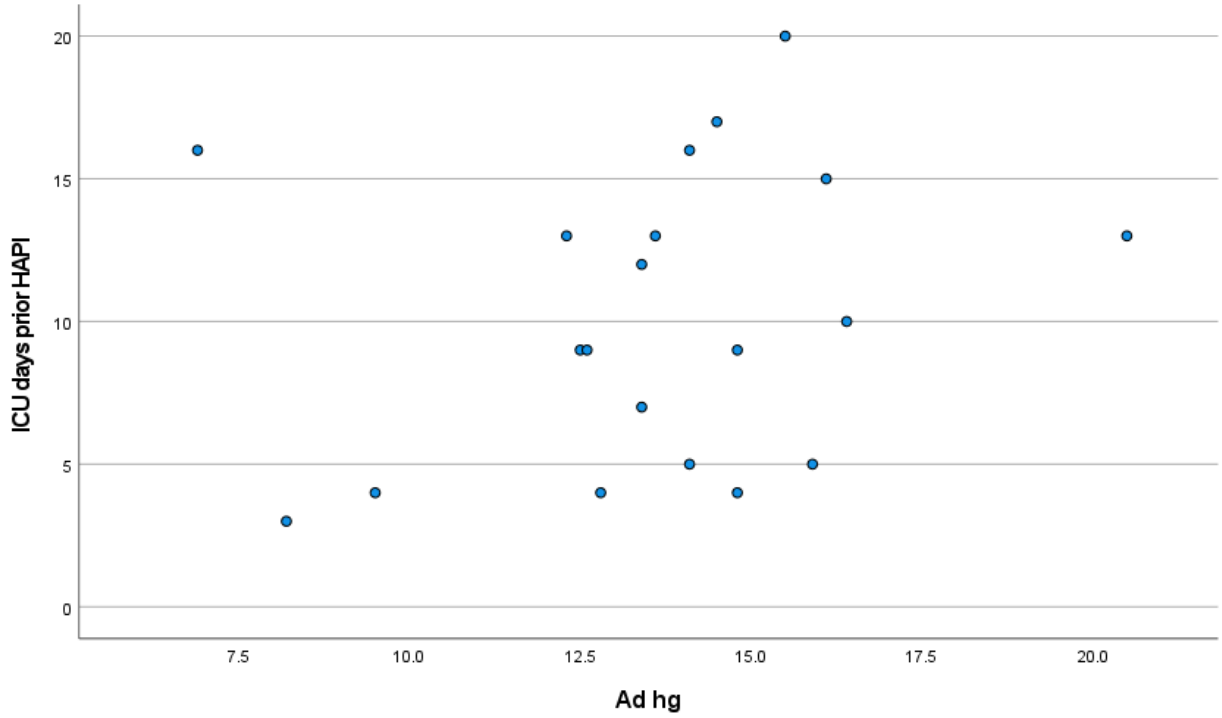
Scatterplots for Tested Correlations

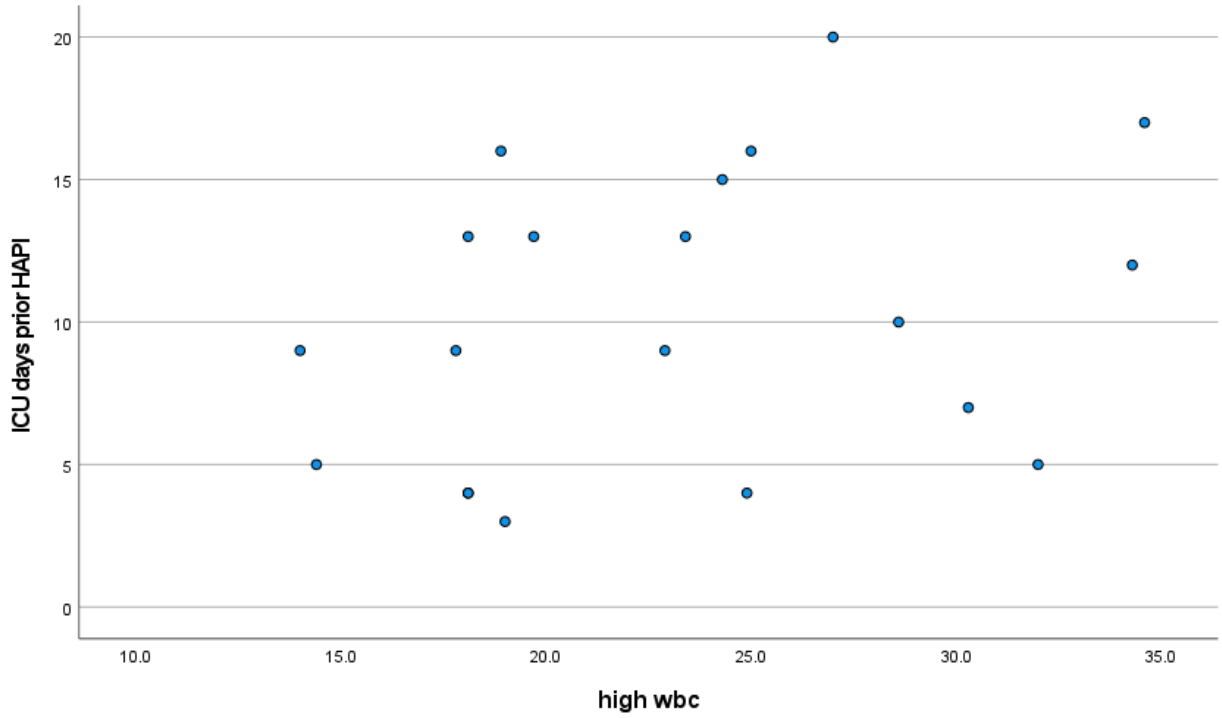


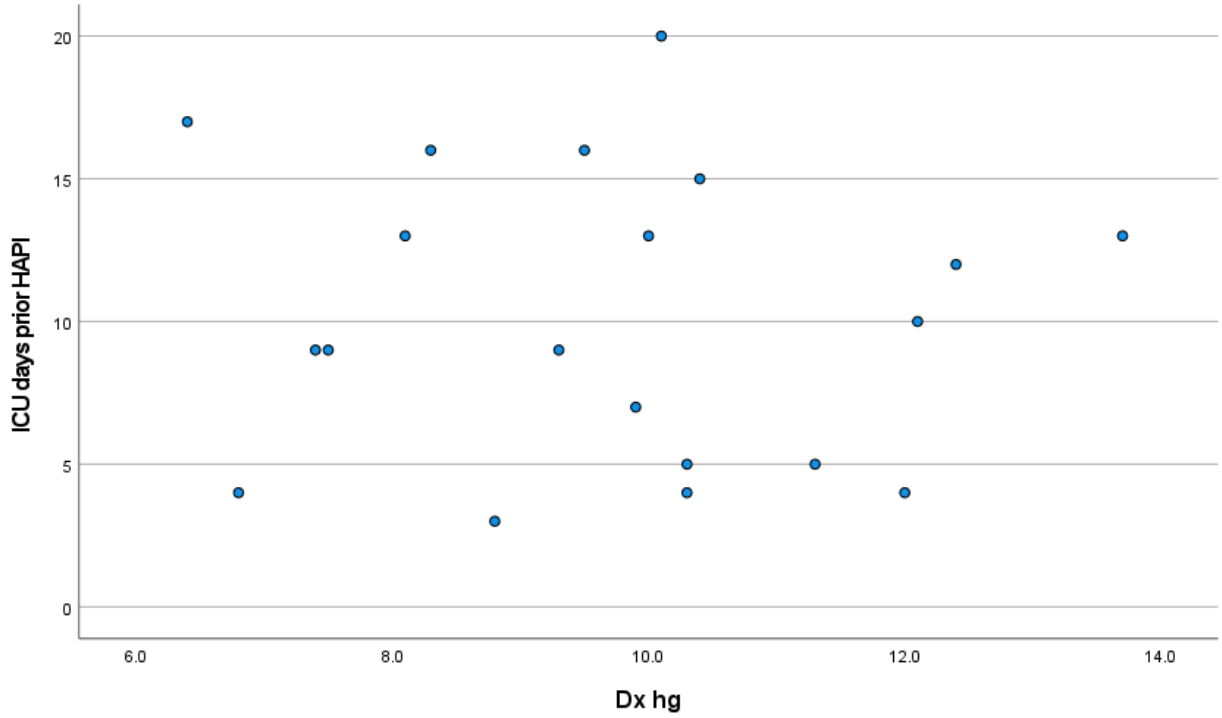


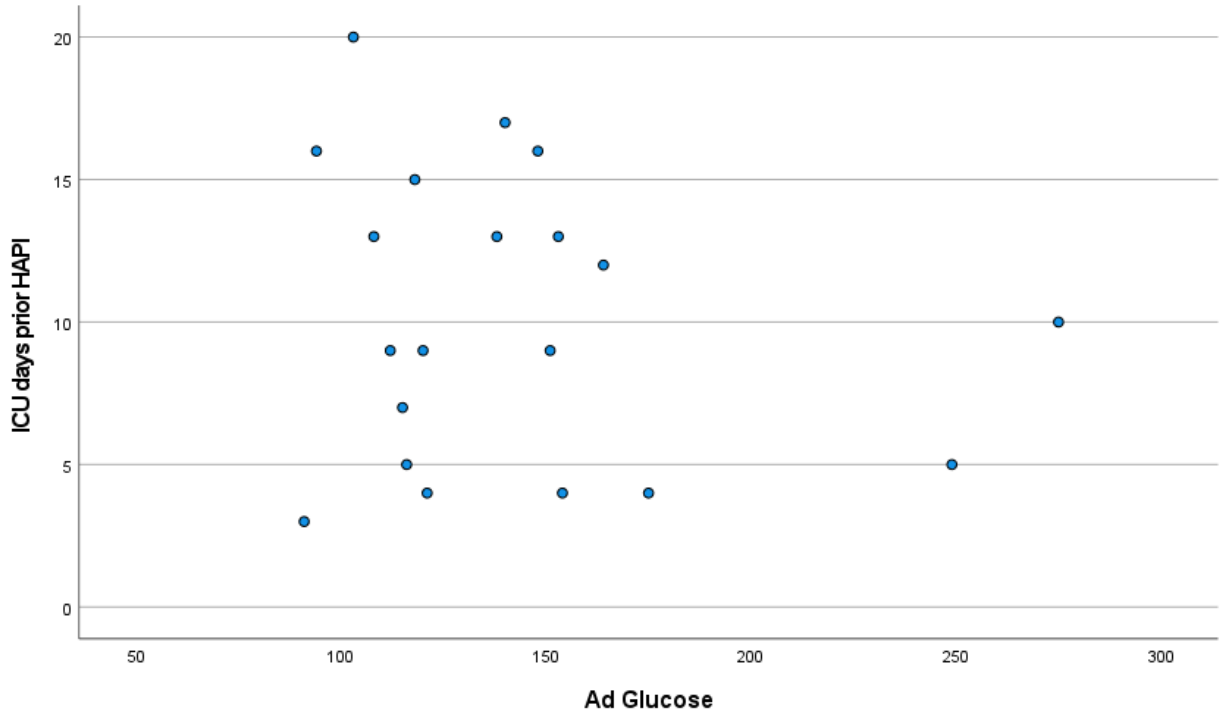

ICU days prior HAPI
20
15
10
5
0
0
5
10
15
20
Vent days

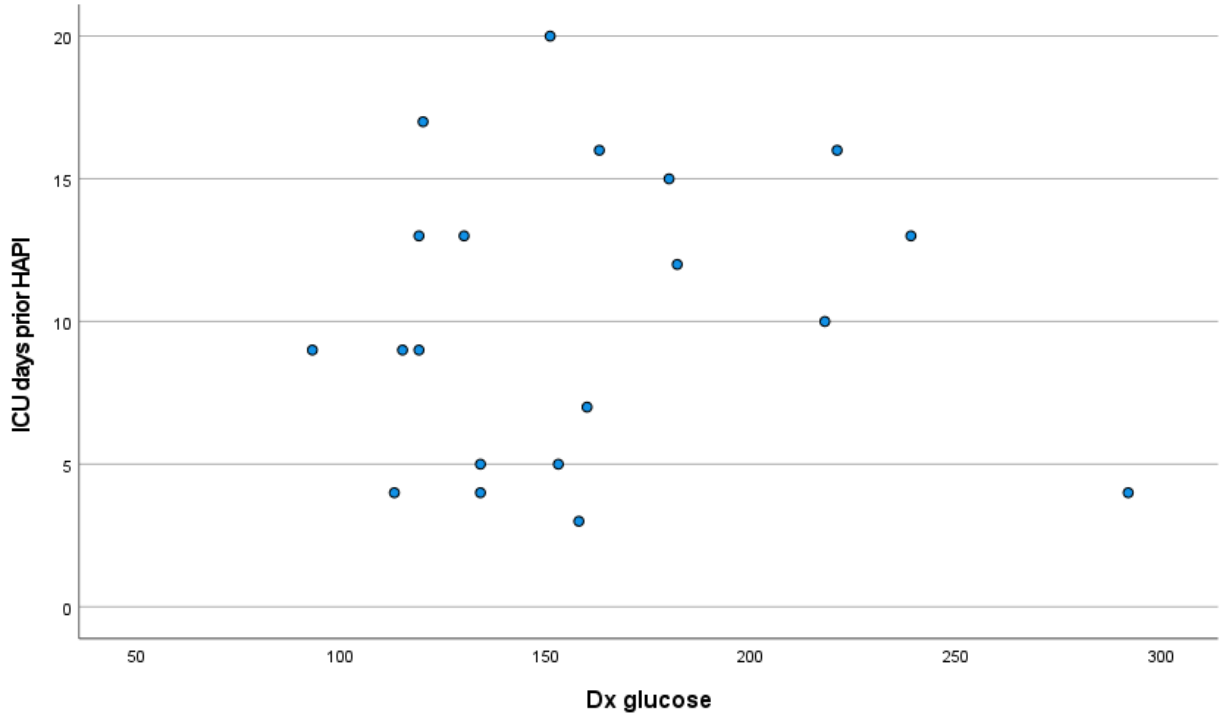

ICU days prior HAPI
20
15
10
5
0
0
2
4
6
8
10
12
14
vasopressor days

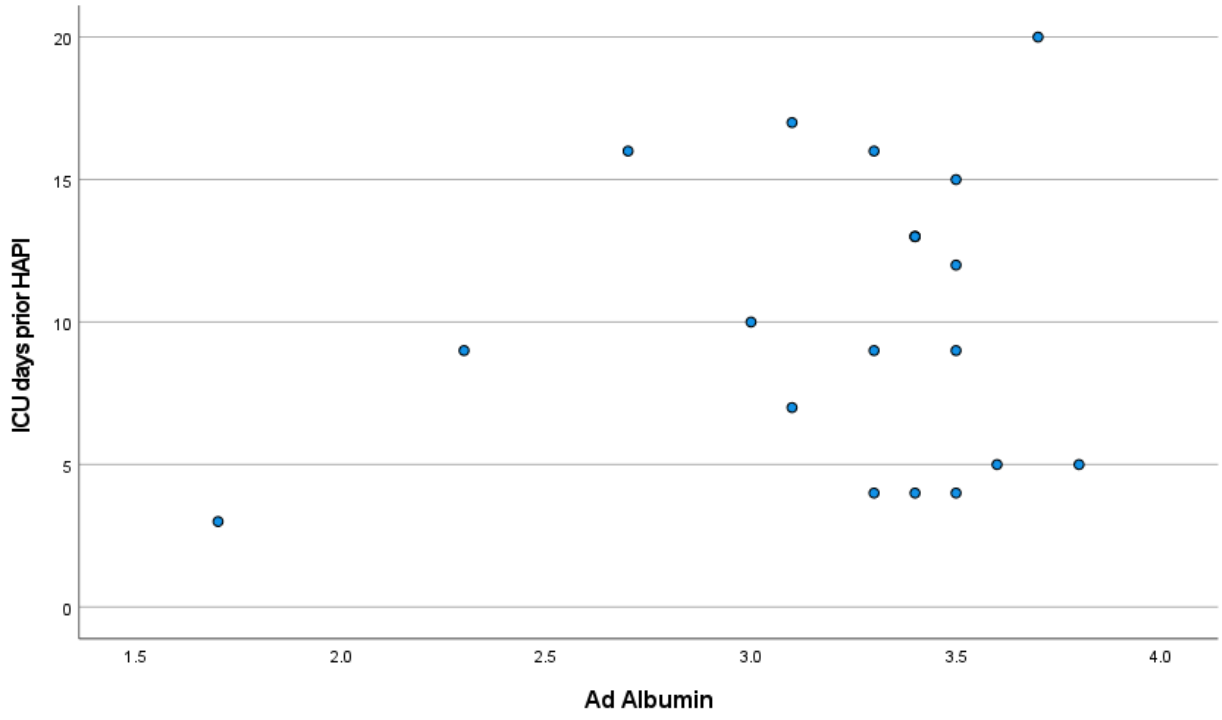

ICU days prior HAPI
20
15
10
5
0
7.5
10.0
12.5
15.0
17.5
20.0
Ad hg

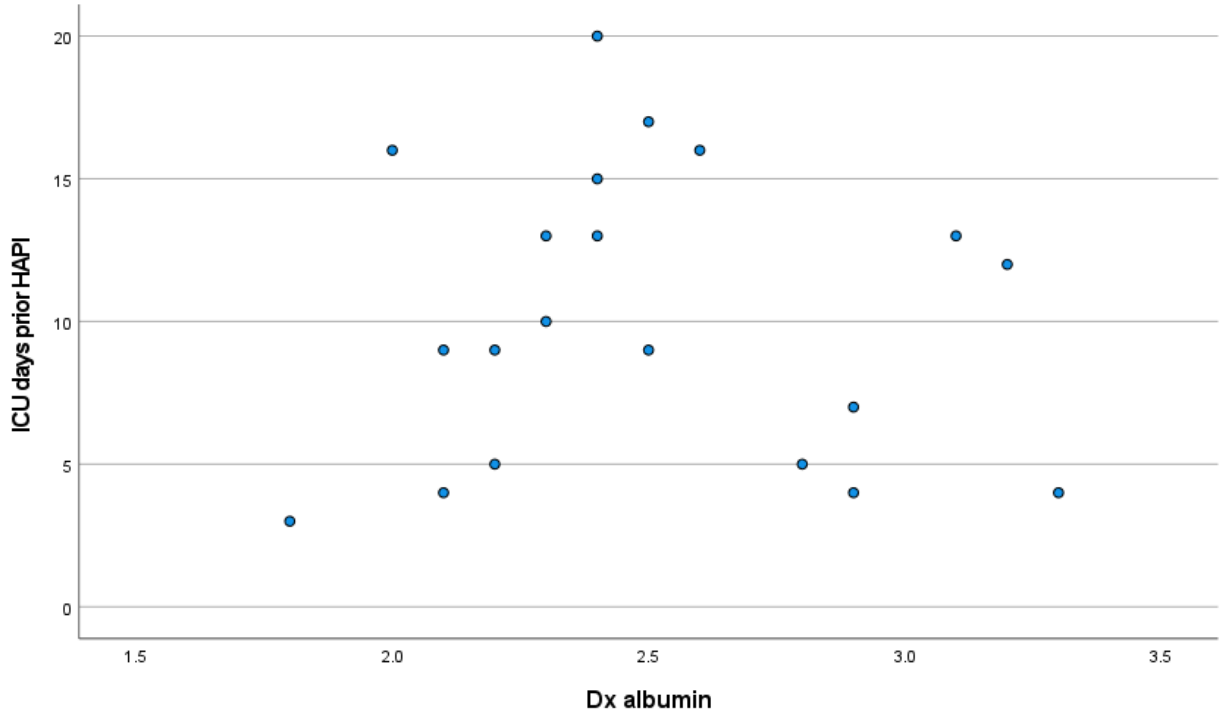

ICU days prior HAPI
20
15
10
5
0
10.0
15.0
20.0
25.0
30.0
35.0
high wbc

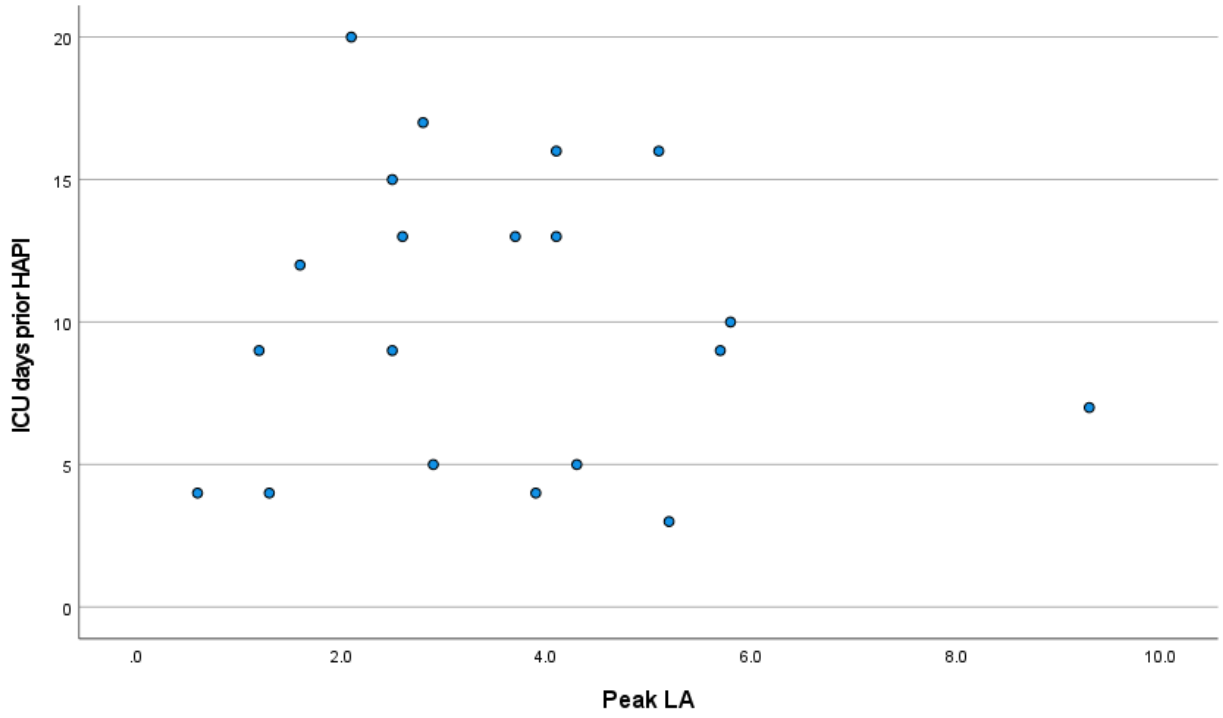

ICU days prior HAPI
20
15
10
5
0
6.0
8.0
10.0
12.0
14.0
Dx hg

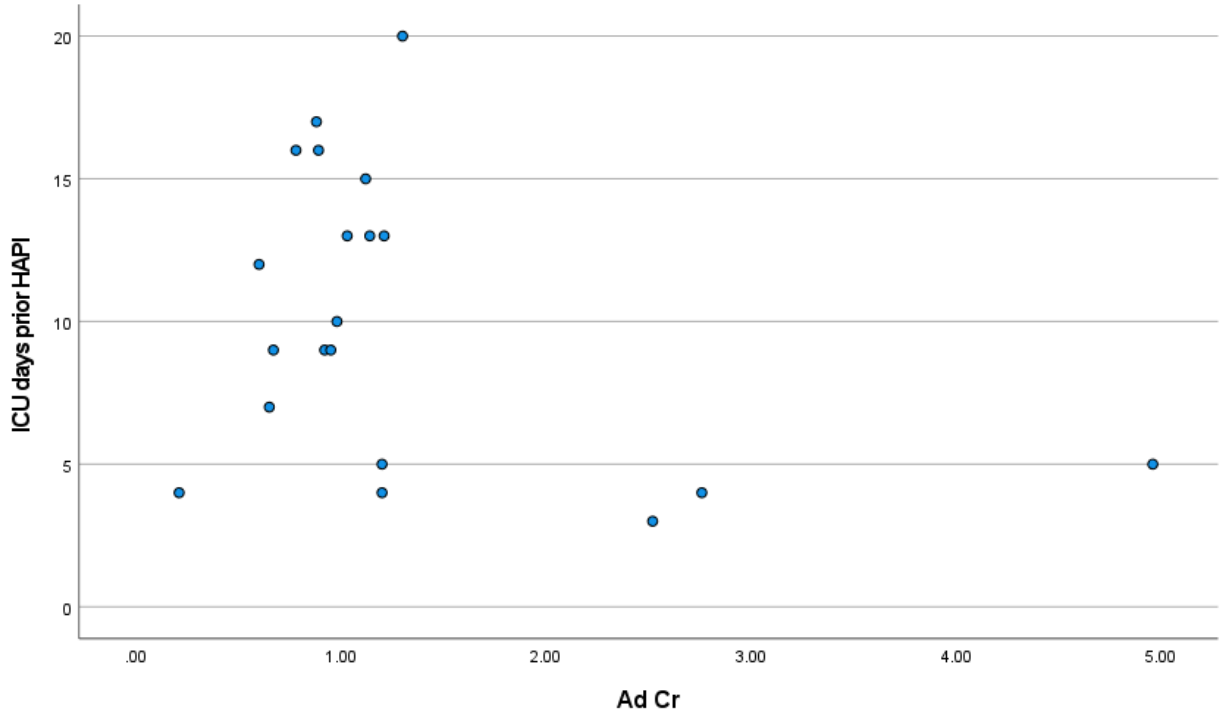

ICU days prior HAPI
20
15
10
5
0
50
100
150
200
250
300
Ad Glucose

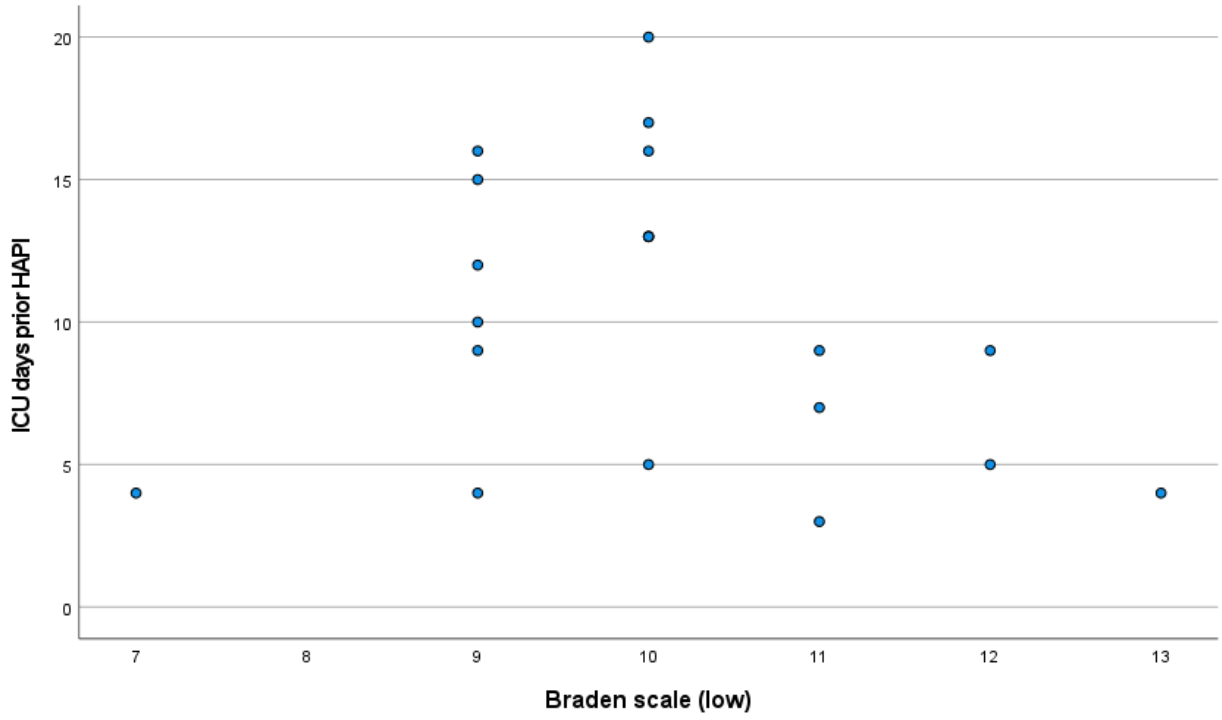

ICU days prior HAPI
20
15
10
5
0
50
100
150
200
250
300
Dx glucose

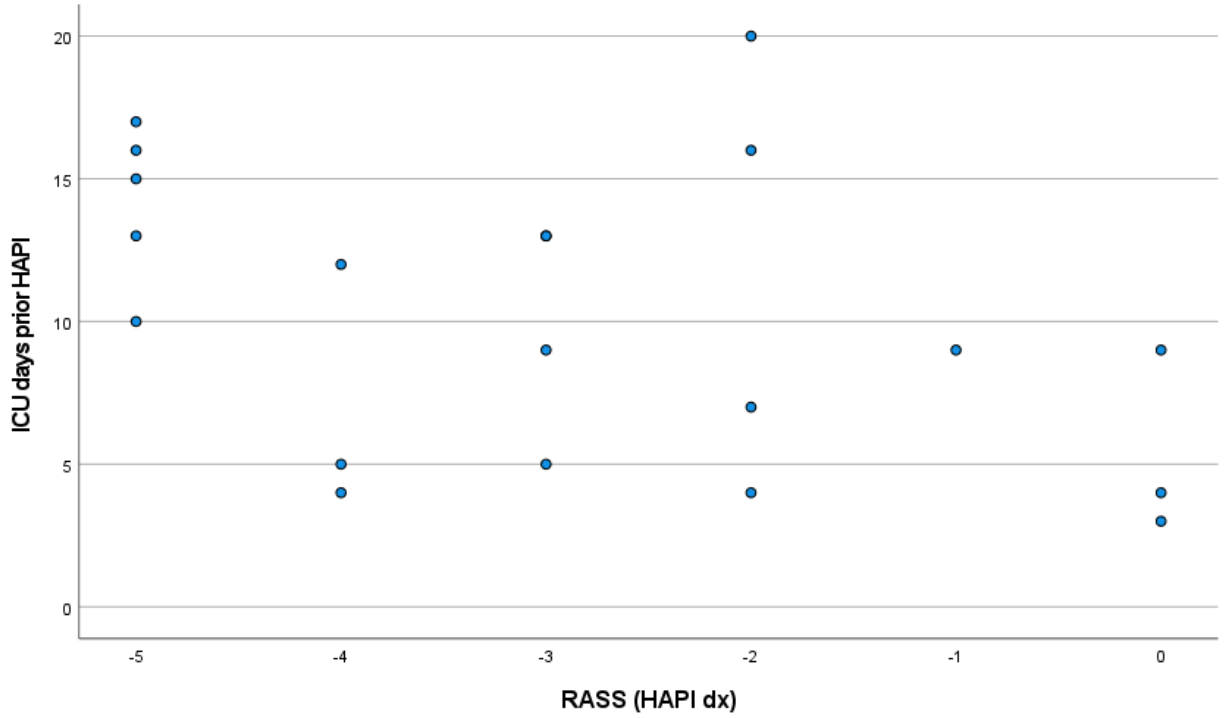

ICU days prior HAPI
20
15
10
5
0
1.5
2.0
2.5
3.0
3.5
4.0
Ad Albumin

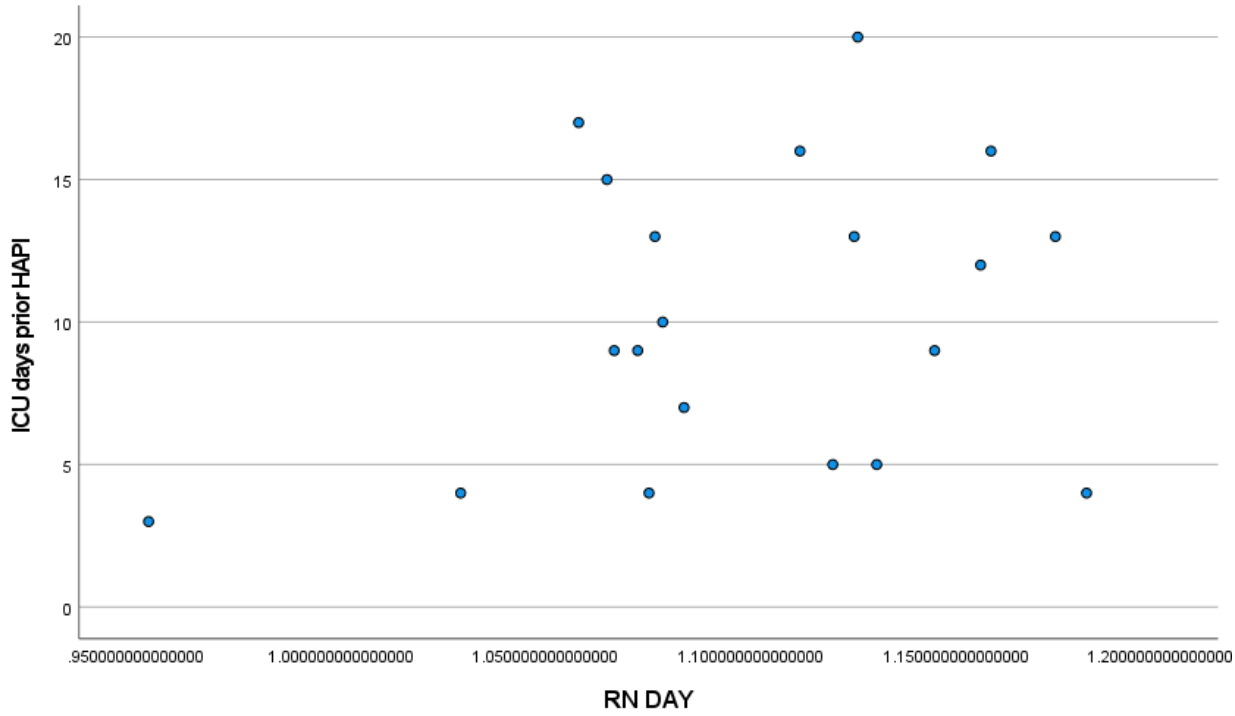

ICU days prior HAPI
20
15
10
5
0
1.5
2.0
2.5
3.0
3.5
Dx albumin

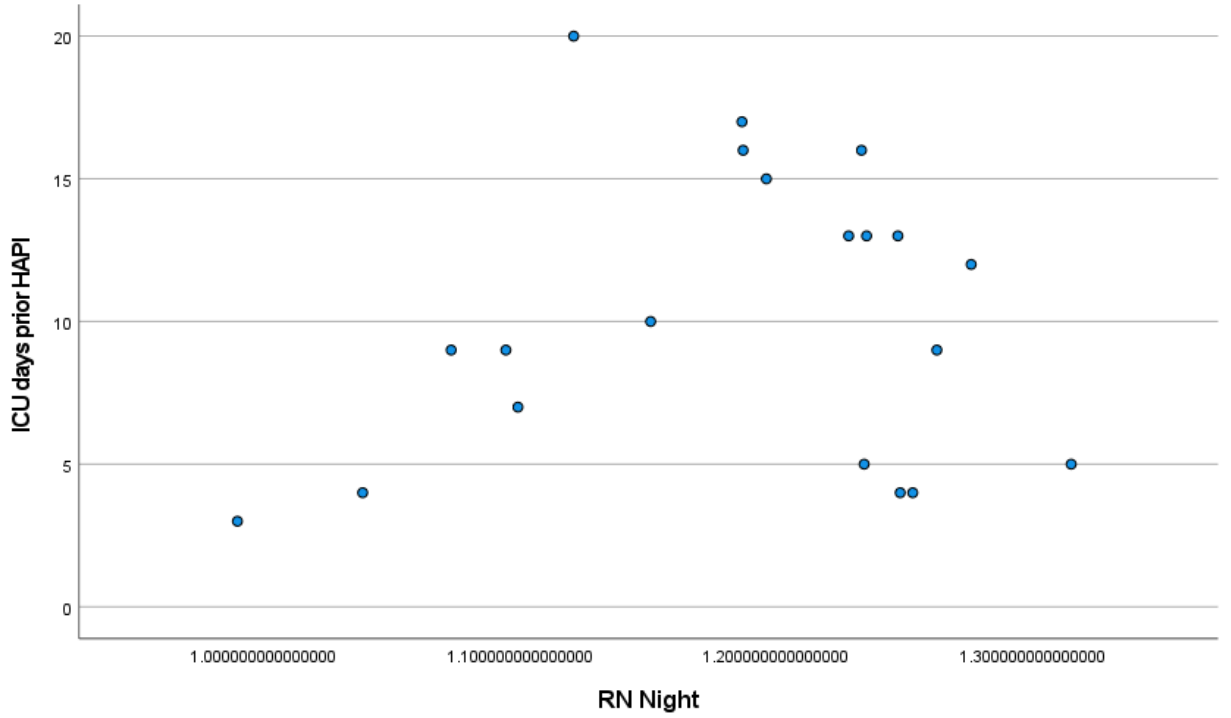

ICU days prior HAPI
20
15
10
5
0
.0
2.0
4.0
6.0
8.0
10.0
Peak LA

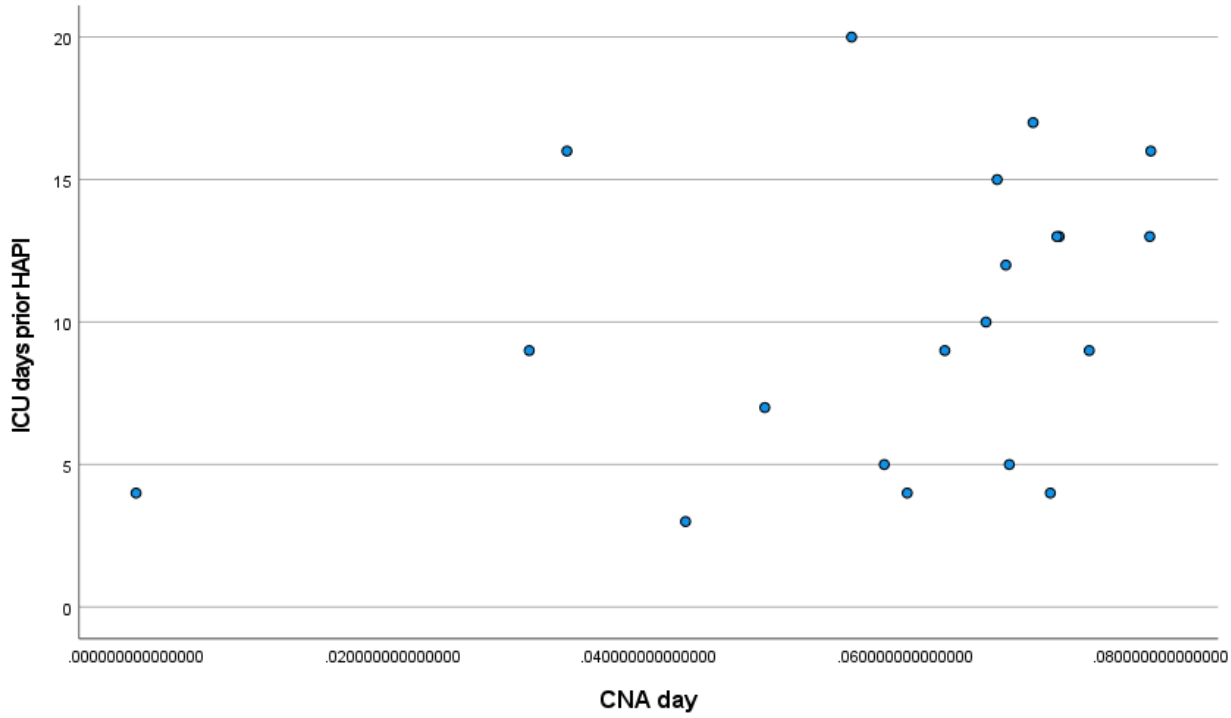

ICU days prior HAPI
20
15
10
5
0
.00
1.00
2.00
3.00
4.00
5.00
Ad Cr

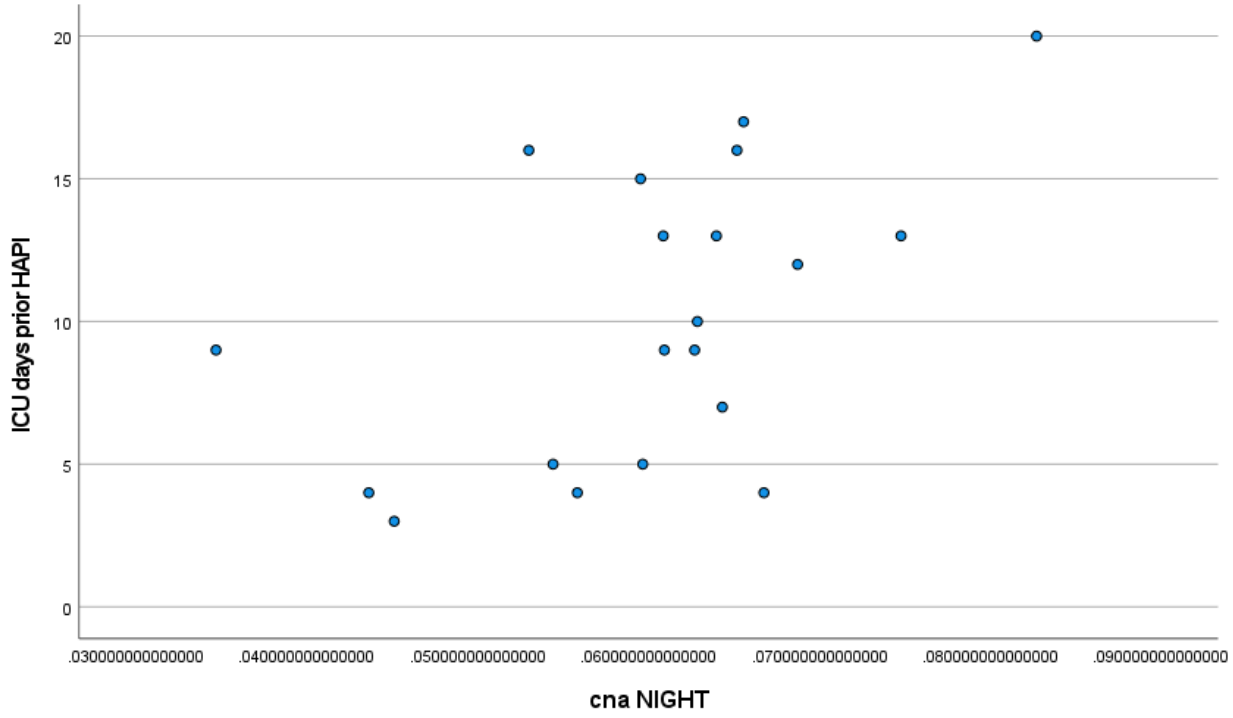

ICU days prior HAPI
20
15
10
5
0
7
8
9
10
11
12
13
Braden scale (low)

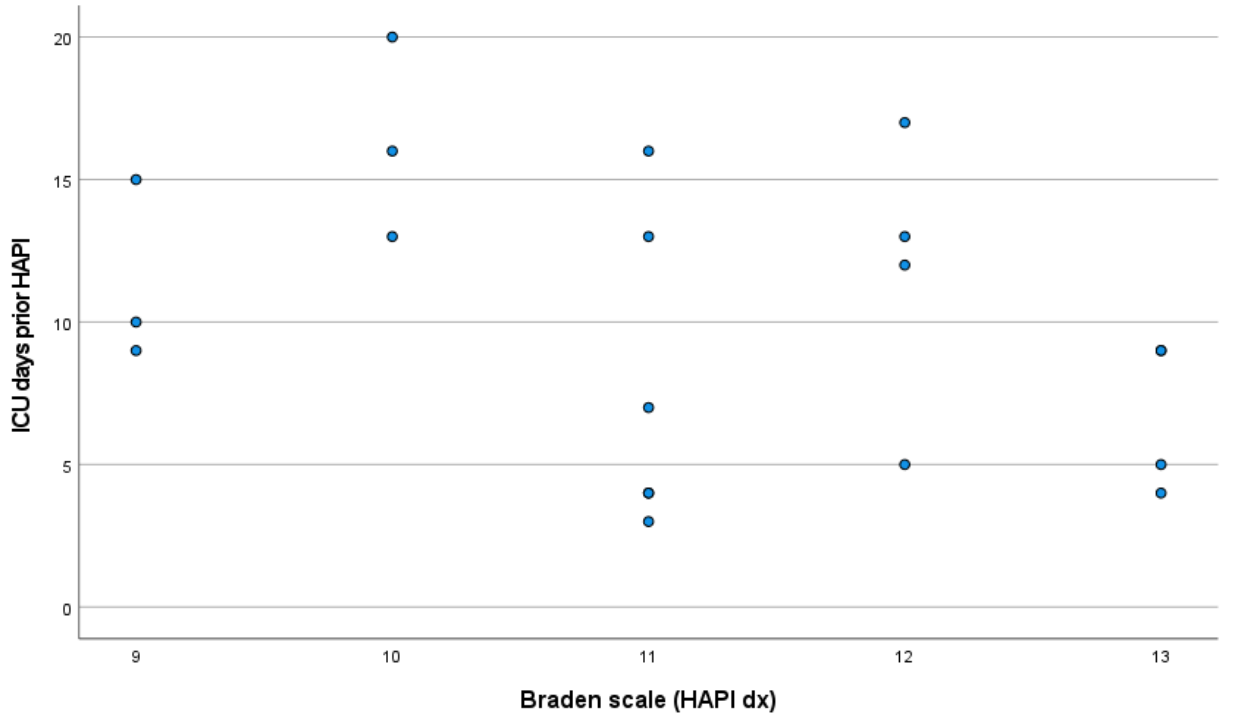

ICU days prior HAPI
20
15
10
5
0
-5
-4
-3
-2
-1
0
RASS (HAPI dx)


ICU days prior HAPI
20
15
10
5
0
.950000000000000
1.000000000000000
1.050000000000000
1.100000000000000
1.150000000000000
1.200000000000000
RN DAY


ICU days prior HAPI
20
15
10
5
0
1.000000000000000
1.100000000000000
1.200000000000000
1.300000000000000
RN Night


ICU days prior HAPI
20
15
10
5
0
.000000000000000
.020000000000000
.040000000000000
.060000000000000
.080000000000000
CNA day


ICU days prior HAPI
20
15
10
5
0
.030000000000000
.040000000000000
.050000000000000
.060000000000000
.070000000000000
.080000000000000
.090000000000000
cna NIGHT


ICU days prior HAPI
20
15
10
5
0
9
10
11
12
13
Braden scale (HAPI dx)

Appendix C

Pearson Correlations

Potentially meaningful at significant ($p < .05$), marginal ($p < .10$) or trend level ($p < .20$)

		MICU days prior to HAPI
Ventilator Days	Pearson Correlation Sig (2-tailed) N	0.902 < 0.001 20
Vasopressor Days	Pearson Correlation Sig (2-tailed) N	0.826 < 0.001 20

		MICU days prior to HAPI
Creatinine (at admission)	Pearson Correlation Sig (2-tailed) N	-0.366 0.112 20

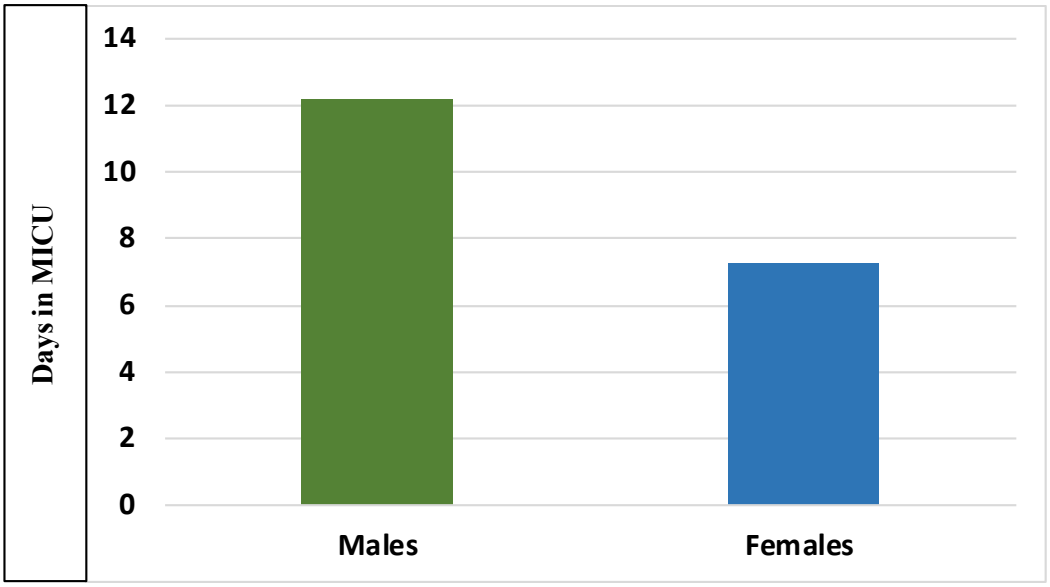
		MICU days prior to HAPI
Braden Score (at HAPI dx)	Pearson Correlation Sig (2-tailed) N	-0.356 0.123 20
RASS score (at HAPI dx)	Pearson Correlation Sig (2-tailed) N	-0.416 0.068 20

		MICU days prior to HAPI
Female Gender	Pearson Correlation Sig (2-tailed) N	-0.484 0.031 20

		MICU days prior to HAPI
RN-to-Pt-Ratio (Days)	Pearson Correlation Sig (2-tailed) N	0.279 0.234 20
RN-to-Pt-Ratio (Nights)	Pearson Correlation Sig (2-tailed) N	0.156 0.512 20
CNA-to-Pt Ratio (Day)	Pearson Correlation Sig (2-tailed) N	0.313 0.18 20
CNA-to-Pt Ratio (Night)	Pearson Correlation Sig (2-tailed) N	0.531 0.016 20

Appendix D

Mean Days in MICU Prior to HAPI Diagnosis



Appendix E

Mean Days in MICU Prior to HAPI Diagnosis