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Approval Sheet

The Association between Interhospital Care Fragmentation on 30-day Readmissions for Hyperglycemic Crisis States and Non-Hyperglycemic Crisis States and Outcomes within the USA in 2018

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2023

Abstract

The Association Between Interhospital Care Fragmentation on 30-day Readmissions for Hyperglycemic and Non-Hyperglycemic Crisis States and Outcomes within the USA in 2018

By: Siri L. Chirumamilla, DO, MS

Background: Hospital readmissions are considered a quality indicator and cost containment metric for hospitals. As a result, healthcare systems have attempted to understand the factors that could cause excess 30-day readmission rates and impact on patient outcomes, which can vary by population, medical or surgical condition, or hospital. One such factor is interhospital care fragmentation, which is readmission to a different hospital from the index admission. While there is information regarding interhospital care fragmentation on certain high-prevalence conditions such as myocardial infarction and heart failure, there is limited information on the impact of interhospital care fragmentation on hyperglycemic crisis states (diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state (HHS)), which result from uncontrolled diabetes mellitus, a disease that affects 37.3 million people (11.3%) within the USA. The focus of the study is to understand the association between interhospital care fragmentation and patient-level outcomes (in-hospital mortality, readmission length-of-stay, readmission cost) in 30-day readmissions among patients initially admitted for hyperglycemic crisis state (DKA/HHS admissions) in a nationally representative dataset in 2018, as well as whether these outcomes differed by whether the readmission was for a hyperglycemic crisis (DKA/HHS readmissions) or some other non-hyperglycemic crisis diagnosis (non-DKA/HHS readmissions).

Methods: Data from the Agency of Healthcare Research and Quality's National Readmission Database (NRD) was utilized to identify index DKA/HHS (DKA/HHS admissions) and associated fragmented 30-day hospital readmissions (based on ICD-10 codes) for diabetes-related hyperglycemic states (DKA/HHS readmission) or readmission for another diagnosis that was non-diabetes-related (Non-DKA/HHS readmission). Logistic and linear regression models were utilized to assess the associations between interhospital fragmentation and patient outcomes during the readmission (in-hospital mortality, length of stay, and cost).

Results: There were 14,917 weighted index DKA/HHS admissions. Among those with DKA/HHS readmissions (n = 8159, 55%), 1605 (20%) were fragmented. Among those with non-DKA/HHS readmissions (n = 6758, 45%), 1665 (25%) were fragmented. Compared to those with nonfragmented DKA/HHS readmissions, those with fragmented DKA/HHS readmissions had no statistically significant difference in the odds of in-hospital mortality, readmission length of stay, and cost. Compared to those with nonfragmented non-DKA/HHS readmissions, those with fragmented non-DKA/HHS readmissions had no statistically significant difference in the odds of in-hospital mortality but did have significantly increased average readmission length of stay by 1.24 days and increased average readmission cost of $19,807.19.

Conclusions: This study found that interhospital care fragmentation did not have a significant impact on readmission patient outcomes such as length of stay, hospital cost, and in-hospital mortality for those patients that had index DKA/HHS admissions and readmitted for hyperglycemic crisis states (DKA/HHS readmissions). In contrast, interhospital care fragmentation did significantly increase readmission length of stay and hospital cost in patients that had index DKA/HHS admissions but readmitted for a non-diabetes-related readmissions (non-DKA/HHS readmissions). This current study reinforces the importance of understanding the impact of interhospital care fragmentation on individual medical conditions and patient outcomes.

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"As we let our own light shine, we unconsciously give other people permission to do the same. As we are liberated from our own fear, our presence automatically liberates others."-Nelson Mandela

This quote resonated with my journey this year, and I would like to thank everyone who supported and inspired me.

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Chapter 1: Introduction

Introduction and rationale

Hospital readmissions are considered a quality indicator and cost containment metric for hospitals. In response, there have been programs such as the Hospital Readmissions Reduction Program (HRRP) focused on reducing readmissions for certain target medical and surgical conditions, including myocardial infarction (MI) or total knee arthroplasty [2]. In addition, healthcare systems have attempted to understand the factors that could cause excess 30-day readmission rates, which can vary by population, condition, or hospital [2]. Life-threatening uncontrolled hyperglycemic states such as diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state (HHS) are not included in the HRRP despite diabetes mellitus being a principal index admission diagnosis ranked third for 30-day all-cause readmissions in 2018 with septicemia and heart failure being ranked first and second respectively [3].

A hospital readmission is a readmission that occurs within a certain pre-defined time (ex: 30-days or 60-days) after an initial admission [4]. A fragmented readmission occurs when a readmission is to a different hospital than the index admission [5]. Previous work has shown that fragmented readmissions may be associated with negative outcomes in certain diagnoses or patient populations, such as congestive heart failure, post-surgical patients, postpartum patients, and socially vulnerable populations [2, 6-8]. Fragmented readmissions have also been shown to have higher mortality rates, longer lengths of hospital stay, and higher cost compared to those readmissions that were non-fragmented [5, 9]. These outcomes varied based on whether the fragmented readmission is for the same reason or a different reason than the index admission [2, 6-8].

Problem Statement

Hospitalization for hyperglycemic crisis states is common and fragmented care may be an unexamined risk factor for poor patient outcomes in this population [9, 10]. As a result, there is a need to understand association between interhospital care fragmentation and patient-level outcomes (in-hospital mortality, readmission length-of-stay, readmission cost) in 30-day readmissions among patients initially admitted for hyperglycemic crisis state (DKA/HHS admissions) in a nationally representative dataset in 2018. Additionally, there is a need to understand if outcomes differed by whether the readmission was for a hyperglycemic crisis (DKA/HHS readmissions) or some other non-hyperglycemic crisis diagnosis (non-DKA/HHS readmissions)

Purpose Statement

The goal of this analysis is to evaluate the prevalence of 30-day DKA/HHS readmissions as well as measure the association between interhospital care fragmentation and readmission length of stay, cost, and in-hospital mortality among 30-day DKA/HHS readmissions utilizing the National Readmission Database (NRD) for 2018. NRD is a nationally representative database that contains unique patient linkage identifiers that allow researchers to track a patient longitudinally over the course of a calendar year [11].

Research Question & Hypothesis

Research Question: Among patients initially admitted for hyperglycemic crisis states, what is the 30-day readmission rate? Among patients initially admitted for hyperglycemic crisis states, what is the association between interhospital care fragmentation and patient-level outcomes (in-hospital mortality, readmission length-of-stay, readmission cost) in 30-day readmissions in a nationally representative dataset in 2018? Do these outcomes differ by whether the readmission is for hyperglycemic crisis (DKA/HHS) or some other non-DKA/HHS diagnosis (non-DKA/HHS)? By addressing these research questions, it will further our knowledge on the role of interhospital care fragmentation on readmissions for uncontrolled hyperglycemic states.

Hypothesis: Overall, irrespective of readmission for DKA/HHS or non-DKA/HHS, fragmented readmissions will have higher costs, longer lengths of stay, and increased in-hospital mortality compared to non-fragmented readmissions.

Theoretical framework

Interhospital care fragmentation occurs when a patient receives care across multiple hospitals or healthcare systems, which has been found to be associated with higher costs, , repetitive diagnostic testing, and other negative health outcomes [9, 10]. In addition, the impact of interhospital care fragmentation could potentially be heightened in vulnerable populations due to potential increased exposures to social or structural determinants of health such as lack of transportation, homelessness, or receipt of care from hospitals that might not have access to hospital discharge teams that can ensure a smooth transition for the patient from the hospital to outpatient care [2, 12, 13]. These outcomes can also vary on whether the fragmented readmission is for the same reason or a different reason than the index admission [2, 6-8]. In an analysis of the 2013 NRD, patients with a fragmented readmission who were readmitted for the same reason as their initial admission had 18% higher odds of in-hospital mortality, a half day increased length of stay, and $1375 greater charges compared to those who had non-fragmented readmissions [5]. Utilizing this information and consideration that the impact of fragmentation on health outcomes might vary by medical condition, this project used a framework that was previously applied in a study examining outcomes following fragmented readmissions (Figure 1) (REF). Here, we focus specifically on fragmented readmissions following index admissions for hyperglycemic crisis states—a reason for hospitalization that increased at a rate of 6.3% per year between 2009-2014 [14].

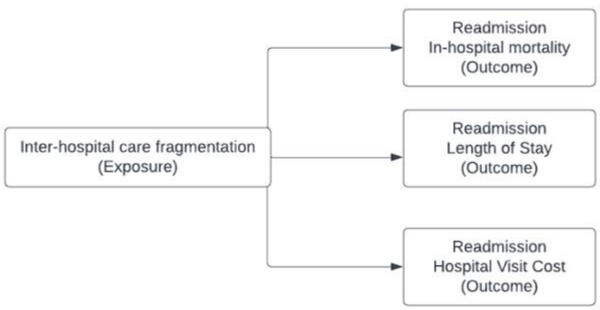

Figure 1: Theoretical Framework of Inter-hosptail care fragmentation (exposure) and patient outcomes

As described in Figure 1, interhospital fragmentation can have an impact on a patient's readmission in-hospital mortality, length of stay, and hospital visit cost. This may be because the index hospital and readmission hospital may not have the infrastructure in place for clinicians to communicate with each other in regards to a patient's previous admission in a timely manner. In addition, due to the lack of this infrastructure, patients might be subjected to repeated labs or diagnostic imaging that can potentially increase in-hospital mortality, length of stay, or hospital cost.

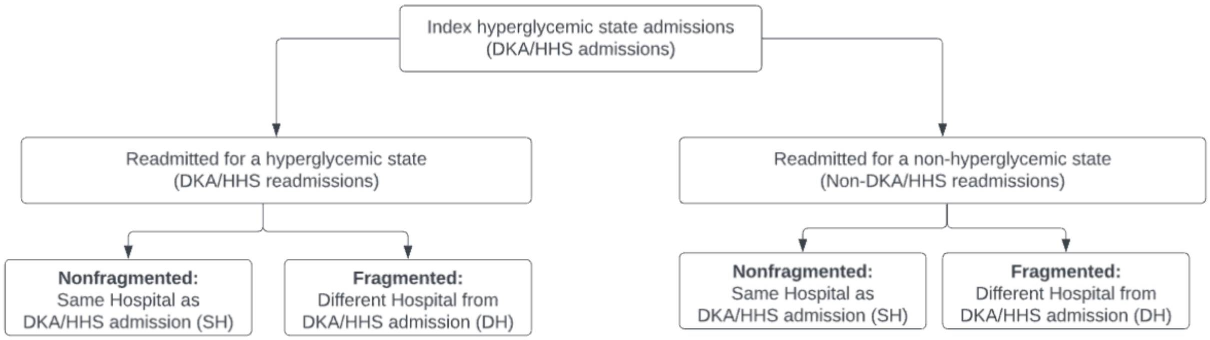

Figure 2: Readmission Diagnosis (DKA/HHS or non-DKA/HHS) Stratification

SH: Same hospital as index DKA/HHS admission

DH: Different hospital from index DKA/HHS admission

As shown in Figure 2, patients were first stratified by readmission diagnosis category (DKA/HHS or non-DKA/HHS). Once stratified by readmission diagnosis category, then patients were further stratified within these subgroups by whether the readmission was fragmented or not. A nonfragmented readmission is defined by a readmission to the same hospital (SH) as the index DKA/HHS admission whereas a fragmented readmission is defined by a readmission to a different hospital (DH) from the index DKA/HHS admission.

Significance Section

Overview of Hospital Readmissions & Impact on Patient Outcomes

Hospital readmissions are considered a quality indicator and cost containment tool for hospitals [1]. Excessive readmissions might impact a patient's choice of choosing a particular hospital for their healthcare needs [4]. In addition, within the US, hospital readmissions can be costly. For example, an analysis of Medicare claims data from 2003-2004 revealed that unplanned readmissions cost $17.4 billion within the United States, which has continued to increase to $26 billion in 2011 [15, 16]. As a result, healthcare systems have attempted to delineate the factors that could cause excess 30-day readmission rates.

In response to the readmissions metric and understanding factors that could impact this metric, there have been programs such as the Hospital Readmissions Reduction Program (HRRP), which focuses on reducing readmissions for certain target medical and surgical conditions [2]. It is important to understand the implications of readmissions on patient care, quality of life, and healthcare costs. For example, for heart failure patients, hospital readmissions are associated with worse health-related quality of life and death [17]. Some strategies that have been utilized by hospitals to reduce hospital readmissions are ensuring a safe post-discharge location, ensuring a safe length of stay, and appropriate discharge timing[18]. While post-hospitalization discharge factors have been utilized strategies to reduce readmission rates, a factor that has not been considered within post-hospitalization discharge is interhospital fragmentation.

Overview of Fragmented Readmissions and Impact on Medical Conditions

A fragmented readmission occurs when a readmission is to a different hospital than the index admission [5]. Previous work has shown that fragmented readmissions may be more strongly associated with negative outcomes for certain diagnoses or patient populations, including chronic conditions such as congestive heart failure, post-surgical patients such as abdominal aortic aneurysm repair, postpartum patient population, socially vulnerable populations; these outcomes may vary based on whether the fragmented readmission is for the same reason or a different reason than the index admission [2, 6-8]. In an analysis of the 2013 NRD, patients with a fragmented readmission who were readmitted for the same reason as their initial admission had 18% higher odds of in-hospital mortality, a half day increased length of stay, and $1375 increased cost compared to those who had non-fragmented readmissions [5].

Diabetes Mellitus USA Prevalence and Implication of Hyperglycemic Crisis States on Patient Outcomes

Diabetes is a common disease within the US: according to the CDC's National Diabetes Statistics Report, 37.3 million people (11.3%) of the US population have diabetes [19]. In 2018, there were 248,000 emergency department visits for hyperglycemic crises with the majority being DKA (223,000 visits) followed by HHS (25,000 visits) [19]. In addition, in 2018, there were 226,000 hospitalizations for DKA/HHS [19]. An example of non-DKA/HHS diagnosis is heart failure. According to the American Heart Association Statistical Update, approximately 6 million people (1.8%) of the US population have heart failure [20]. In addition, based on a 2006-2014 analysis of Healthcare Cost and Utilization Project Nationwide Emergency Department Sample (NEDS), there were 1.1 million emergency department visits and 1 million hospitalizations for heart failure [21]. There have been multiple studies on the impact of care fragmentation on heart failure readmission outcomes [5, 6, 17]. In contrast, there is limited information on the impact of care fragmentation on DKA/HHS readmission outcomes such as in-hospital mortality, length of stay, and hospital cost. This can have major implications. For example, diabetes as a disease has a high cost burden within the US. In 2017, people who were diagnosed with diabetes within the US had estimated direct medical costs of $237 billion, a significant increase from $188 billion in 2012 [19]. In addition,

The purpose of this thesis is to evaluate the association between interhospital care fragmentation on patient outcomes including cost of the readmission, in-hospital mortality, and length of stay for 30-day readmissions following diabetes-related hyperglycemic crisis states index admissions (DKA/HHS admissions) stratified by whether the readmission is for the same diabetes-related hyperglycemic state (DKA/HHS readmissions) or a different diagnosis (non-DKA/HHS readmissions) in a nationally representative sample from 2018.

Definition of terms

The exposure for this study is interhospital care fragmentation. A nonfragmented hospital readmission is when a patient is admitted to the same hospital as the index admission. A fragmented readmission is when a patient is admitted to a different hospital than the index admission.

As noted in Figure 2, the study population was first selected by index hyperglycemic state admissions (DKA/HHS admissions) and then stratified by their readmission for hyperglycemic state (DKA/HHS readmissions) or non-hyperglycemic state (non-DKA/HHS readmissions). Next, each group was stratified by interhospital care fragmentation. The non-fragmented group was the respective reference for the DKA/HHS readmissions or non-DKA/HHS readmissions group.

The patient outcomes for this study were readmission in-hospital mortality, readmission length of stay, and readmission hospital cost.

Chapter 2: Review of the Literature

Overview of Hospital Readmissions & Impact on Patient Outcomes

Hospital readmissions are considered a quality indicator and a cost containment metric by hospitals[1]. Within the US, approximately 13% of hospitalized patients that are readmitted utilize more than half the hospital's resources [22]. Also, within the US, hospital readmissions can be expensive. For example, an analysis of Medicare claims data from 2003-2004 revealed that unplanned readmissions cost $17.4 billion within the United States, which has continued to increase to $26 billion in 2011 [15, 16]. As a result, healthcare systems have attempted to delineate the factors that could cause excess 30-day readmission rates. For example, for heart failure patients, hospital readmissions are associated with worse health-related quality of life and death [17]. While post-hospitalization discharge factors have been utilized strategies to reduce readmission rates such as safe post-discharge location or appropriate discharge timing, a factor that might not always be considered when patients are readmitted to the hospital is whether their care has been fragmented, in particular interhospital fragmentation. [18].

Overview of Ambulatory Care Fragmentation

Care fragmentation occurs when a patient receives care from multiple providers in the outpatient setting [23]. Fragmented care in the outpatient setting is very common: a 2005 study of Medicare beneficiaries found that a single primary care physician would have to communicate with 99 other physicians and 53 other practices to care for 100 patients [24, 25].

In addition, care fragmentation in the outpatient setting is considered a risk factor for hospitalization [24]. A retrospective secondary data analysis of Medicare fee-for-service claims within the REGARDS (Reasons for Geographic and Racial Differences in Stroke) study between

2003-2016 found that fragmented ambulatory care was independently associated with incident stroke care among African Americans with fair or poor health [26]. Ambulatory care fragmentation can have a negative impact on patient outcomes such as poor quality of life and increased healthcare expenditure. For example, a retrospective review of patients with multiple chronic conditions from insurance claims data between 2004-2008, patients that received fragmented primary care had $4252 increased healthcare spending as well as higher rates of preventable hospitalizations [27].

Overview of Interhospital Care Fragmentation

While most examinations of care fragmentation have focused on the outpatient setting, fragmentation can also occur within the inpatient settings as well. Interhospital care fragmentation can be defined as a patient being readmitted to a different hospital than they were originally discharged from [9]. Interhospital care fragmentation studies in the literature tend to focus on certain populations with specific emphasis on postoperative patients, which has shown mixed associations with patient outcomes [7, 28, 29]. For example, in a study of patients who had a transcatheter mitral valve edge-to-edge (TEER) repair between 2014-2018, fragmented interhospital postoperative care was not associated with higher rates of adverse events and was not associated with 180-day mortality [29]. On the other hand, for patients who underwent major cancer surgery between January 1 to September 30, 2013, a fragmented 90-day readmission resulted in 31.2% higher odds of mortality and 27.3% higher odds of major complications [28].

More recently, there have been studies in the literature regarding interhospital care fragmentation for acute medical conditions such as myocardial infarction (MI), chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), and stroke [5, 6, 30-32]. For example, compared to CHF patients with fragmented readmissions, CHF patients that were readmitted to the index hospital (non-fragmented) had lower mortality rates (14.4% vs 15.0%) and shorter length of stay (10.4 days vs 11.6 days) [6]. There has been one previous study of the effect of care fragmentation on hyperglycemic crisis states. This 2006-2012 study used the Chicago HealthLNK Data Repository (CHDR), an electronic health record linkage tool from 4 academic medical centers and 1 county healthcare system to track admissions and readmissions for patients with DKA. It found that 16% of DKA patients with more than one admission were hospitalized at more than one hospital (i.e., had a fragmented readmission) [31]. However, this study was limited to the medical centers in Chicago that participated in HealthLNK [31]. To our knowledge, there is no national-level investigation of the prevalence of fragmented readmissions among patients with DKA/HHS.

Overview of DKA/HHS Readmissions and The Role of Fragmentation

It is crucial to gain an understanding of the national picture of fragmented readmissions in DKA/HHS and its associated outcomes because DKA and HHS admissions are common and increasing in frequency. In 2018, there were 248,000 emergency department visits for hyperglycemic crises with the majority being DKA (223, 000 visits) followed by HHS (25,000 visits) [19]. In addition, in 2018, there were 226,000 hospitalizations for DKA/HHS [19]. DKA hospitalizations have increased annually at a rate of 6% or more from 2009 to 2014 and cost expenditure estimated at greater than 2.4 billion dollars [14, 32-36]. Inpatient mortality for HHS is approximately 10-fold higher than DKA [14]. According to retrospective review of DKA discharges between 2010-2014 within the National Readmission Database, 12.3% of DKA admissions were readmitted within 30 days and recurrent DKA discharges were 40.8% of all-cause readmissions [34].

The diagnosis of the readmission can also affect outcomes in fragmented readmissions [5]. Certain readmission diagnoses such as myocardial infarction which have standardized protocols and most likely are similar between different hospitals might not be affected as much by fragmentation compared to diagnoses that might not have structured protocols such as COPD or CHF where the regimen can be slightly modified based on clinical judgement [5]. Patient outcomes can also vary on whether the fragmented readmission was for the same reason or different reason than the index admission [2, 6-8]. In addition, hyperglycemic crisis such as HHS has 20% mortality despite being less than 1% of hospital admission while DKA mortality is greater than 5% in the elderly and other life-threatening conditions [35, 37]. There have been no previous examinations of whether the effects of a fragmented readmission on patient outcomes following an initial admission for DKA/HHS vary by whether the readmission is also for DKA/HHS versus a non-DKA/HHS diagnosis.

The purpose of this study was to evaluate the general prevalence of 30-day readmissions for hyperglycemic crisis states (DKA and HHS) as well as the association between interhospital care fragmentation and in-hospital mortality, readmission length of stay, and readmission hospital cost among DM and non-DKA/HHS readmissions, utilizing the National Readmission Database for 2018.

Chapter 3: Methodology

Data Source, Population and Sample

This was a secondary data analysis conducted utilizing the Agency for Healthcare Research and Quality's (AHRQ) [11] National Readmission Database (NRD). NRD is a nationally representative dataset containing all non-federal hospital admissions and readmissions within a calendar year. The year used for this study was 2018. The analysis was limited to the first admission-readmission dyad of the time period. All patients who were 18 years and older originally admitted for DKA or HHS (DKA/HHS admissions: defined as admission diagnoses with primary ICD-10 codes of E0900, E0901, E0910, E0911, E1010, E1011, E1100, E1101, E1110, E1111, E1300, E1301, E1310, E1311) with 30-day readmissions between January and December 2018 were included.

Patients were divided into two groups: those with readmissions for DKA/HHS (DKA/HHS readmissions) and those whose readmissions were not for DKA/HHS (non-DKA/HHS readmissions). For example, a patient who was initially admitted for DKA/HHS and then had a readmission for DKA/HHS would be in the DKA/HHS readmission group. A patient who was initially admitted for DKA/HHS and then readmitted for pneumonia would be in the non-DKA/HHS readmissions group. Then, the two readmission groups were further stratified by whether the readmission was fragmented or not. Nonfragmented readmissions were those who were admitted to the same hospital (SH) as the index admission and fragmented readmissions were those who were admitted to a different hospital (DH) as the index admission. The nonfragmented readmission groups served as reference to their respective fragmented readmission group counterpart as shown in Figure 2.

Research Design

Data Analysis and Methodology

Utilizing weighted procedures provided by AHRQ, univariate demographic and hospital characteristics were described for the DKA/HHS and non-DKA/HHS readmissions groups across fragmentation status (fragmented versus non-fragmented). Next, unadjusted and adjusted logistic and linear regression models were used to evaluate the 3 readmission patient outcomes (in-hospital mortality, length of stay, cost) for admission-readmission pairs for fragmented versus non-fragmented DM and non-DKA/HHS readmissions, respectively. In addition, a sensitivity analysis was done that compared patient outcomes among four groups: DKA admissions/DKA readmissions, HHS admissions/HHS readmissions, Myocardial Infarction (MI) admissions/MI readmissions, Sepsis admissions/Sepsis readmissions.

Within this study, there were 3 regression models that were utilized to understand the association between interhospital care fragmentation (exposure) and readmission patient outcomes (in-hospital mortality, readmission length of stay, readmission hospital cost) as well as the sensitivity analyses.

Each of the three models below were run for each of the patient outcomes. The co-variates that were included within each model in addition to the interhospital care fragmentation exposure were added in groups and are below:

Model 1: Fragmentation (primary exposure), age, sex, insurance, zip income quartile, Elixhauser mortality risk score, index admission length of stay, index admission cost

Model 2: Fragmentation (primary exposure), Model 1 covariates, Readmission Major Diagnostic Category

Model 3: Fragmentation (primary exposure), Model 2 covariates, hospital characteristics (hospital bed size, hospital control/ownership, hospital teaching status, hospital urban/rural designation).

All analyses within this study were completed with SAS 9.4 (SAS Institute). The study was exempt from review by Emory University Institutional Review Board

Chapter 4: Results

Key findings

After removing discharges for patients <18 years old, interhospital transfers, changing the unit of observation to be admission-readmission pairs, our weighted analytic sample contained 14,917 index admissions for DKA/HHS (DKA/HHS admissions). All results presented are weighted to provide national-level estimates. As shown in Table 1, Of the 14,917 DKA/HHS admissions, 8159 (54.7%) were DKA/HHS readmissions and 6758 (45.3%) were readmitted for non-DKA/HHS readmissions. Of the DKA/HHS readmissions (n = 8159), 1605 (20%) readmissions were fragmented and 6554 (80%) readmissions were nonfragmented. Of the non-DKA/HHS readmission (n = 6758), 1665 (25%) readmissions were fragmented and 5093 (75%) were nonfragmented. Compared to DKA/HHS readmissions, non-DKA/HHS readmissions had a longer mean length of stay (5.80 days vs 3.34 days, $p < 0.0001$), higher total hospital charges ($32977.00 vs $31201.53, $p < 0.0001$), and higher readmission in-hospital mortality (2.09% vs 0.28%, $p < 0.0001$).

<u>*DKA/HHS Readmission Group*</u>

Demographics and Clinical Characteristics: As shown in Table 2A, compared to those that had a nonfragmented DKA/HHS readmission, patients that had a fragmented DKA/HHS readmission were younger (35.75 years vs 37.91 years, $p < 0.001$). There was no significant difference in lower zip income quartiles and insurance payer. In terms of clinical characteristics, patients that had a fragmented DKA/HHS readmission had a significantly lower Elixhauser mortality risk score (-4.04 vs -3.69, $p = 0.02$). There were no significant differences in index admission length of stay (3.09 vs 3.13 days, p = 0.17) and cost ($32238.62 vs $30049.95, p-value = 0.47) between fragmented and nonfragmented DKA/HHS readmissions.

Hospital Characteristics: As shown in Table 2B, compared to those that had a nonfragmented DKA/HHS readmission, patients that had a fragmented readmission were primarily at a metropolitan teaching hospitals (71.46% vs 63.24%, p < 0.001) in a large metropolitan area with at least 1 million residents (59.50% vs 45.86%, p < 0.001).

Patient Outcomes: As shown in Table 1, compared to those that had a nonfragmented DKA/HHS readmission, those with a fragmented DKA/HHS readmission had a significantly higher in-hospital mortality (0.37% vs 0.26%, p-value < 0.001) and readmission cost ($33140.91 vs $30726.18, p-value = 0.008). There was no significant difference in readmission length of stay between fragmented and non-fragmented DKA/HHS readmissions (3.33 days vs 3.34 days, p = 0.94).

Non-DKA/HHS Readmission Group

Demographics and Clinical Characteristics: As shown in Table 3A, compared to those that had a nonfragmented non-DKA/HHS readmissions, patients that had a fragmented non-DKA/HHS readmission were younger (46.73 years vs 49.69 years, p < 0.001), more likely to be from a lower zip income quartile (44.37% vs 39.21%,p = 0.002) and less likely to have Medicare insurance (38.23% vs 43.39%, p < 0.001) and had an increased index admission length of stay (4.48 vs 4.74, p = 0.0002). In terms of clinical characteristics, patients that had a fragmented non-DKA/HHS readmission had a significantly lower Elixhauser mortality risk score (-2.84 vs -2.26, p = 0.001).

Hospital Characteristics: As shown in Table 3B, compared to those that had a nonfragmented non-DKA/HHS readmission, patients that had a fragmented non-DKA/HHS readmission were primarily at a metropolitan teaching hospital (72.85% vs 68.75%, p-value = 0.0004) in a large metropolitan area with at least 1 million residents (62.88% vs 51.86%, p-value < 0.0001).

Patient Outcomes: As shown in Table 1, compared to those had a nonfragmented non-DKA/HHS readmission, those with fragmented non-DKA/HHS readmission had a significantly higher in-hospital mortality (2.16% vs 2.06%, p-value < 0.001), longer readmission length of stay (6.63 days vs 5.53 days, p < 0.001), and higher readmission cost ($72215.49 vs $53485.72, p < 0.001).

DKA/HHS Readmissions Modeling Analysis: Association between Fragmentation and Patient Outcomes

As shown in Table 4, in an unadjusted analysis, compared to a nonfragmented DKA/HHS readmission, those that had a fragmented DKA/HHS readmission had no statistically significant difference in the odds of in-hospital mortality (OR 0.66, 95% CI 0.25, 1.70) nor in readmission length of stay (regression coefficient 0.02, 95% CI -0.23, 0.82). In contrast, compared to those that had a nonfragmented DKA/HHS readmission, those with fragmented DKA/HHS readmission had an increased readmission cost of $2121.53 (95% CI $271.33, $3971.72). In an adjusted analysis for demographic analysis, readmission major diagnostic categories, and hospital characteristics (Model 3) as shown in Table 4, compared to a nonfragmented DKA/HHS readmission, those that had a fragmented DKA/HHS readmission had no statistically significant difference in odds of in-hospital mortality (AOR 0.58, 95% CI 0.22, 1.50) nor in readmission length of stay (regression coefficient 0.06, 95% CI -0.14, 0.26), or readmission cost ($889.42, 95% CI: $-768.61, $2457.44).

Non-DKA/HHS Readmissions Modeling Analysis: Association between Fragmentation and Patient Outcomes

As shown in Table 5, in an unadjusted analysis, compared to a nonfragmented non-DKA/HHS readmission, those that had a fragmented non-DKA/HHS readmission had no statistically significant difference in the odds of in-hospital mortality (OR 0.84, 95% CI 0.55, 1.28). In contrast, compared to those that had a nonfragmented non-DKA/HHS readmission, those with a fragmented non-DKA/HHS readmission had a statistically significant increased length of stay (regression coefficient 1.21 95% CI 0.68, 1.75) and increased readmission cost ($19843.72, 95% CI: $11990.18, $27697.27). In adjusted analysis for demographic analysis, major diagnostic categories, and hospital characteristics (Model 3) as shown in Table 5, compared to a nonfragmented non-DKA/HHS readmission, those that had a fragmented non-DKA/HHS readmission had no statistically significant difference in the odds of in-hospital mortality (AOR 0.70, 95% CI 0.46, 1.07). In contrast, compared to those that had a nonfragmented non-DKA/HHS readmission, those with a fragmented non-DKA/HHS readmission had a statistically significant increased length of stay (regression coefficient 1.24, 95% CI 0.70, 1.77) and increased readmission cost ($19807.19, 95% CI $12172.73, $27441.65).

Sensitivity Analysis

A sensitivity analysis was done utilizing the same model covariates as noted above with four groups noted below. The results of these analyses are shown in Tables 6-9

- DKA (DKA admissions/DKA readmissions versus DKA admissions/non-DKA readmissions)
- HHS (HHS admissions/HHS readmissions versus HHS admissions/non-HHS readmissions)
- Myocardial Infarction (MI admissions/MI readmissions versus MI admissions/non-MI readmissions)
- Sepsis (Sepsis admissions/Sepsis readmissions versus Sepsis admission/non-Sepsis readmissions).

Of these groups, the estimates for DKA and sepsis are presented below with results shown in Tables 6 and 9 respectively. HHS and MI sensitivity analyses also shown in tables 7 and 8 respectively, but were not included in the discussion as there were not valid estimates due to low number of cases.

DKA Sensitivity Analysis

As shown in Table 6 for DKA admissions/DKA readmissions group, in an unadjusted analysis, compared to a nonfragmented readmission, those that had a fragmented readmission had no statistically significant difference in the odds of readmission in-hospital mortality (OR 0.76, 95% CI 0.27, 2.11) and readmission length of stay (regression coefficient 0.002, 95% CI -0.204, 0.209). In contrast, compared to a nonfragmented readmission, those that had a fragmented readmission had a statistically significant difference in readmission cost ($2184.15, 95% CI $312.16, $4056.15).

This is in contrast, in an adjusted analysis for demographic characteristics, readmission major diagnostic categories, and hospital characteristics (Model 3) as shown in Table 6, compared to a nonfragmented readmission, those that had a fragmented readmission had no statistically significant difference in the odds of readmission in-hospital mortality (AOR 0.67, 95% CI 0.24, 1.86), readmission length of stay (regression coefficient 0.09, 95% CI -0.11, 0.29), and readmission cost ($1017.43, 95% CI $-643.42, $2678.27).This is in contrast to the DKA admissions/non-DKA readmissions group, which had significant findings in readmission length of stay (regression coefficient 1.20, 95% CI 0.61, 1.78) and readmission cost ($19526.34, 95% CI $11065.21, $27987.37) once adjusted for demographic characteristics, readmission major diagnostic categories, and hospital characteristics (Table 6, Model 3)

Sepsis Sensitivity Analysis

Diabetes mellitus is considered a co-morbid condition that can affect the prognosis of multiple conditions such as sepsis due to compounded worsening inflammation and dyresgulated immune pathways [38]. For this sensitivity analysis, DKA/HHS admissions/Sepsis admissions and DKA/HHS admissions/non-Sepsis admissions were analyzed.

As shown in Table 9 for DKA/HHS admissions/Sepsis readmissions group, in an unadjusted analysis, compared to a nonfragmented readmission, those that had a fragmented readmission had no statistically significant difference in the odds of readmission in-hospital mortality (OR 0.82, 95% CI 0.19, 3.56), readmission length of stay (regression coefficient -1.45, 95% CI -4.68, 1.78). and readmission cost ($30271.16, 95% CI: -$26931.93, $97474.24). In an adjusted analysis for demographic characteristics, readmission major diagnostic categories, and hospital characteristics (Model 3) as shown in Table 9, compared to a nonfragmented readmission, those that had a fragmented readmission had no statistically significant difference in the odds of readmission in-hospital mortality (AOR 0.98, 95% CI 0.17, 5.50), readmission length of stay (regression coefficient 0.12, 95% CI -2.47, 2.71), and readmission cost ($43157.85, 95% CI $-27694.92, $114010.61).

This is in contrast to the DKA/HHS admissions/non-Sepsis readmissions group, which had significant findings for in-hospital mortality (aOR 0.50, 95% CI 0.41, 0.62), readmission length of stay (regression coefficient 0.60, 95% CI 0.32, 0.89) and readmission cost ($9559.42, 95% CI $5708.95, $13409.89) once controlled for demographic characteristics, readmission major diagnostic categories, and hospital characteristics (Table 9, Model 3).

Summary

Among DKA/HHS readmissions, after adjusting for patient demographics, index admission covariates, major diagnostic categories, and hospital characteristics, fragmentation was not associated with readmission in-hospital mortality, readmission length of stay, and readmission cost. In contrast, for non-DKA/HHS readmissions, there was no statistically significant difference in odds of in-hospital mortality between non-fragmented and fragmented non-DKA/HHS, but there was a statistically significantly longer readmission length of stay and higher readmission cost. These findings were replicated in our sensitivity analyses as well.

Chapter 5: Discussion

Summary of Study

The goal of this analysis was to describe the prevalence of 30-day DKA/HHS readmissions as well as to measure the association between interhospital care fragmentation and readmission length of stay, cost, and in-hospital mortality outcomes among 30-day DKA/HHS readmissions. For index DKA/HHS admission and DKA/HHS readmission pairs, once adjusted for patient demographics, index admission covariates, major diagnostic categories, and hospital characteristics, it appears that fragmentation did not have a statistically significant association with in-hospital mortality, length of stay, and hospital cost. In contrast, for index DKA/HHS admission and non-DKA/HHS readmission pairs, compared to those that had a non-fragmented non-DKA/HHS readmission, those with fragmented non-DKA/HHS readmission had around a 1-day longer length of stay (regression coefficient 1.24, 95% CI 0.70, 1.77), and nearly $20,000 higher readmission costs ($19807.19, 95% CI $12172.73, $27441.65).

Discussion of Key Results

As described earlier, the association between fragmented readmissions and patient outcomes has shown mixed results across different patient populations [5, 6, 30-32]. Here, we found that the association of fragmented readmissions differs greatly in patients with index admissions for DKA/HHS, largely by whether they were readmitted for DKA/HHS or for a different reason.

A possible explanation as to the reason there was not a significant difference in mortality for fragmented and nonfragmented DKA/HHS readmissions could be due to the difference in health status of the groups. The DKA/HHS readmission group was overall younger (nonfragmented: 37.91 years, fragmented: 35.75 years) and had lower Elixhauser mortality risk score, a comorbidity index, (nonfragmented: 3.13, fragmented: 3.09) compared to the non-DKA/HHS readmissions group (nonfragmented: 49.69 years, Elixhauser score: 4.74, fragmented: 46.73 years, Elixhauser score: 4.48). In addition, diabetes mellitus also is considered a comorbidity that can result in the poor prognosis of multiple medical conditions including myocardial infarction or sepsis ([38, 39]. For example, patients with Type 2 diabetes have a greater than 40% risk of MI recurrence compared to those who do not have diabetes mellitus [39]. As a result, a sensitivity analysis was run to determine if DKA/HHS admissions who were readmitted for MI or sepsis possibly had a higher mortality. Within this analysis, there were not enough DKA/HHS admission-MI readmission pairs to run the analysis. For the DKA/HHS admissions-Sepsis readmission pairs, there were no statistically significant difference in the odds of readmission in-hospital mortality, which further lends to the notion that the health status could have been a potential factor as to the reasons there was not a significant difference in mortality.

Another possible explanation why there was not a significant difference in mortality for fragmented and nonfragmented DKA/HHS readmissions could be the initial stratification of the groups. There is a specific subset of hyperglycemic crisis patients that have features of both DKA and HHS, and this group has a twofold increase in mortality compared to isolated DKA or HHS admissions [40]. While we did group DKA or HHS isolated diagnoses under the same umbrella of DKA/HHS readmissions, this particular combined DKA/HHS subset might not necessarily be captured with the current ICD-10 diagnosis codes. In parallel, our study utilized only the first admission-readmission pair within the time period, and therefore patients with recurrent DKA or recurrent HHS admissions would not be captured. Recurrent DKA readmissions, at least 3 or more readmissions, have a twofold increase in all-cause mortality compared to those with single admissions [41]. Another possible explanation as to the lack of a significant difference for readmission in-hospital mortality between nonfragmented and fragmented DKA/HHS readmissions could be that that mortality itself from these conditions have decreased due to improvement in early diagnosis and standardized protocols within the inpatient setting [42].

Thirdly, a possible explanation for no significant difference in mortality for fragmented versus nonfragmented non-DKA/HHS readmissions could be that fragmentation as an exposure could affect patient outcomes themselves differently based on the condition being reviewed. For example, in a secondary 2013 NRD data analysis done by Turbow and colleagues [5], there no significant association between myocardial infarction and mortality, but for COPD and CHF patients, a fragmented readmission with a different diagnosis than the index admission resulted in about 40% higher odds of in-hospital mortality (COPD AOR: 1.41, 95% CI: 1-17-1.71 and CHF AOR: 1.43, 95% CI: 1.25-1.62).

In addition to mortality, there were not significant differences in readmission length of stay or readmission cost in the adjusted models for DKA/HHS readmissions, which can potentially be attributed to the standardized protocolization of DKA/HHS treatments, which might be protective compared to medical diagnoses that might not have a standardized protocol for treatments. Lastly, another consideration to be considered for the DKA/HHS readmissions' non-significant differences in mortality, readmission length of stay or readmission cost could be that this group could have increased exposures to social and structural determinants of health. For example, for type 1 diabetic adults, low socioeconomic status was a strong predictor of DKA readmissions [43]. Another finding that was notable within this study was that within the non-DKA/HHS readmissions group, fragmented readmissions accounted for statistically significant increased readmission length of stay and readmission cost even after adjustment for demographic characteristics, readmission major diagnostic categories and hospital characteristics. This could potentially occur if the non-DKA/HHS readmission diagnoses do not have standard of care and structured treatment protocols in place for their management. In addition, another potential explanation could be information discontinuity, which is when hospitals might not be able to share information regarding a patient in a timely manner due to utilization of different health information exchange (HIEs) systems [44]. If readmission clinical teams do not have access to information from the previous admission, then this could potentially lead to longer lengths of stay and cost.

S*trengths and Limitations of Study*

One strength of the study was being able to utilize a nationally representative sample to review the association between interhospital fragmentation on hyperglycemic crisis state readmissions and its impact on patient outcomes. A limitation of the study is the NRD is that the data is limited to just hospitalizations and does not take into accounts outpatient care management factors or social and structural determinants of health. Secondly, another limitation is that this analysis based on the stratification had relatively small sample size admission-readmission pairs, which may have limited the power to assess differences between the groups robustly. Thirdly, the NRD did not have additional information regarding whether the index admission was where the patient usually gets their care or whether the readmission hospital was whether the patient usually get their care. Also, while the overall finding of the study was that interhospital fragmentation did not have an impact on DKA/HHS readmissions, this finding might not be generalizable to all medical conditions such as CHF or COPD [5, 6]. Another limitation could be how that readmission diagnoses were narrowly selected based on ICD-10 diagnoses codes, which could be affected by how healthcare providers coded the particular admission. In addition, if a patient had concurrent

DKA and HSS, then these high-risk group would not be captured within this dataset. Lastly, another limitation could be the inclusion of January 2018 admissions within the sample as some of these admissions might be readmissions from December 2017. This is not taken into account since the NRD are only hospitalizations within the year being analyzed, and for this study was 2018 only.

Conclusion

This study was able to add to the current literature that interhospital care fragmentation did not have a significant impact on DKA/HHS readmissions in regards to in-hospital mortality, length of stay, and cost. In addition, this study revealed that non-DKA/HHS readmissions had an increased readmission length of stay and increased readmission cost. This current study reinforces the importance of understanding the impact of interhospital care fragmentation on individual medical conditions and patient outcomes. A potential future direction could be to further delineate the differences within and between these groups by considering the impact of social and structural determinants of health and ambulatory care fragmentation factors, and potentially utilize these areas as intervention targets for improvement.

Chapter 6: Tables

Table 1: Unadjusted Outcomes in DKA/HHS and Non-DKA/HHS Readmissions

Patient Outcomes	DKA/HHS Readmissions			Non-DKA/HHS Readmissions		
	Nonfragmented (SH/SD) n = 6553	Fragmented (DH/SD) n = 1605	p-value	Nonfragmented (SH/DD) n = 5094	Fragmented (DH/DD) n = 1665	p-value
In-Hospital Mortality (readmission)	17 (0.26%)	6 (0.37%)	< 0.001	105 (2.06%)	36 (2.16%)	< 0.001
Readmission length of stay in days	3.34 (0.05)	3.33 (0.10)	0.94	5.53 (0.10)	6.63 (0.23)	< 0.001
Readmission cost in $	30726.18 (405.26)	33140.91 (818.55)	0.008	53485.72 (1146.86)	72215.49 (3368.60)	< 0.001

Table 2A: DKA/HHS readmissions Stratified by Fragmentation: Demographics

Patent Demographics	DKA/HHS Readmissions		
	Nonfragmented (SH/SD) n = 6553	Fragmented (DH/SD) n = 1605	p-value
Female	3322 (50.69%)	822 (51.21%)	0.71
Age in years (mean)	37.91 (0.20)	35.75 (0.35)	< 0.001
Zip Income Quartile			
$1-$45,999	2785 (42.83%)	732 (46.21%)	0.06
$46,000-$58,999	1886 (29.00%)	446 (28.16%)	
$59,000-$78,999	1228 (18.88%)	262 (16.54%)	
>$79,000	604 (9.29%)	144 (9.09%)	
Insurance Payer			
Medicare	1648 (25.19%)	306 (19.09%)	0.06
Medicaid	2819 (43.08%)	797 (49.72%)	
Private	992 (15.16%)	233 (14.54%)	
Self-Pay	782 (11.95%)	183 (11.42%)	
No charge	106 (11.62%)	32 (2.00%)	
Other	196 (3.00%)	52 (3.24%)	
Elixhauser Mortality Risk Score	-3.69 (5.27)	-4.04 (5.14)	0.02
Mean Length of Stay in days (first admission)	3.13 (0.04)	3.09 (0.08)	0.17
Mean Cost in $ (first admission)	30049.95 (356.35)	32238.62 (815.55)	0.47

Table 2B: DKA/HHS Readmissions Stratified by Fragmentation: Hospital Characteristics

Hospital Characteristics	DKA/HHS Readmissions		
	Nonfragmented (SH/SD) n = 6553	Fragmented (DH/SD) n = 1605	p-value
Control/Ownership of Hospital (readmission)			
Government, nonfederal	943 (14.39%)	248 (15.45%)	0.002
Private, not-profit	4774 (72.85%)	1104 (68.79%)	
Private, invest-own	836 (12.76%)	253 (15.76%)	
Teaching Status of Hospital (readmission)			
Metropolitan (non-teaching)	1554 (23.71%)	340 (21.18%)	< 0.001
Metropolitan (teaching)	4144 (63.24%)	1147 (71.46%)	
Non-metropolital hospital	855 (13.05%)	118 (7.35%)	
Hospital Urban-Rural Designation (readmission)			
Large Metropolitan areas with at least 1 million residents	3005 (45.86%)	955 (59.50%)	< 0.001
Small Metropolitan areas with less than 1 million residents	2693 (41.10%)	532 (33.15%)	
Micropolitan areas	686B(10.47%)	83 (5.17%)	
Not metropolitan or micropolitan (non-urban residual)	169 (2.58%)	35 (2.18%)	
Hospital Bedsize (readmission)			
Small	1049 (16.01%)	307 (19.13%)	0.006
Medium	1854 (28.29%)	458 (28.54%)	
Large	3650 (55.70%)	840 (52.34%)	

Table 3A: Non-DKA/HHS Readmissions Stratified by Fragmentation: Demographics

Patent Demographics	Non-DKA/HHS Readmissions Nonfragmented (SH/DD) n = 5094	Fragmented (DH/DD) n = 1665	p-value
Female	2654 (52.10%)	827 (49.67%)	0.08
Age in years (mean)	49.69 (0.24)	46.73 (0.40)	< 0.001
Zip Income Quartile			
$1-$45,999	1976 (39.21%)	729 (44.37%)	0.002
$46,000-$58,999	1402 (27.82%)	418 (25.44%)	
$59,000-$78,999	1083 (21.49%)	312 (18.99%)	
>$79,000	578 (11.47%)	184 (11.20%)	
Insurance Payer			
Medicare	2208 (43.39%)	635 (38.23%)	< 0.001
Medicaid	1619 (31.81%)	623 (37.51%)	
Private	780 (15.33%)	220 (13.25%)	
Self-Pay	335 (6.58%)	124 (7.47%)	
No charge	40 (0.79%)	25 (1.51%)	
Other	107 (2.10%)	34 (2.05%)	
Elixhauser Mortality Risk Score	-2.26 (6.66)	-2.84 (6.23)	0.001
Length of Stay in days (first admission)	4.74 (0.09)	4.48 (0.15)	0.0002
Cost in $ (first admission)	45834 (879.65)	44308 (1328.46)	0.48

Table 3B: Non-DKA/HHS Readmissions Stratified by Fragmentation: Hospital Characteristics

Hospital Characteristics	Non-DKA/HHS Readmissions Nonfragmented (SH/DD) n = 5094	Fragmented (DH/DD) n = 1665	p-value
Control/Ownership of Hospital (readmission)			
Government, nonfederal	625 (12.27%)	206 (12.37%)	<0.0001
Private, not-profit	3778 (74.17%)	1159 (69.61%)	
Private, invest-own	691 (13.56%)	300 (18.02%)	
Teaching Status of Hospital (readmission)			
Metropolitan (non-teaching)	1143 (22.44%)	351 (21.08%)	0.0004
Metropolitan (teaching)	3502 (68.75%)	1213 (72.85%)	
Non-metropolital hospital	449 (8.81%)	101 (6.07%)	
Hospital Urban-Rural Designation (readmission)			
Large Metropolitan areas with at least 1 million residents	2642 (51.86%)	1047 (62.88%)	< 0.0001
Small Metropolitan areas with less than 1 million residents	2003 (39.32%)	517 (31.05%)	
Micropolitan areas	370 (7.26%)	68 (4.08%)	
Not metropolitan or micropolitan (non-urban residual)	79 (1.55%)	33 (1.98%)	
Hospital Bedsize (readmission)			
Small	731 (14.35%)	278 (16.70%)	0.03
Medium	1375 (26.99%)	463 (27.81%)	
Large	2988 (58.66%)	924 (55.50%)	

Table 4: DKA/HHS Readmissions: Association between Fragmentation and Patient Readmission Outcomes (In-hospital Mortality, Length of Stay, and Hospital Cost)

Outcome	DKA/HHS readmissions			
	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	0.66 (0.25, 1.70)	0.57 (0.22, 1.47)	0.58 (0.23, 1.51)	0.58 (0.22, 1.50)
Readmission length of stay in days	-0.02 (-0.23, 0.82)	0.06 (-0.13, 0.26)	0.06 (-0.13, 0.26)	0.06 (-0.14, 0.26)
Readmission cost in $	2121.53 (271.33, 3971.73)	1255.74 (-178.33, 2689.82)	1256.22 (-177.87, 2690.32)	889.42 (-768.61, 2547.44)

Model 1: Fragmentation (primary exposure), Age, Sex, Insurance, Zip Income Quartile, Elixhauser Mortality Risk Score, Index admission length of stay, Index admission hospital cost
Model 2: Fragmentation (primary exposure), Model 1 covariates, Readmission Major Diagnostic Category
Model 3: Fragmentation (primary exposure), Model 2 covariates Hospital Bedsize * Hospital Control/Ownership * Hospital Teaching Status * Hospital Urban-Rural Designation
Reference group: Nonfragmented DKA/HHS Readmission
Statistically significant outcomes highlighted in yellow

Table 5: Non-DKA/HHS Readmissions: Association between Fragmentation and Patient Readmission Outcomes (In-hospital Mortality, Length of Stay, and Hospital Cost) for non-DKA/HHS readmissions

Outcome	Non-DKA/HHS readmissions			
	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	0.84 (0.55, 1.28)	0.73 (0.48, 1.11)	0.71 (0.46, 1.09)	0.70 (0.46, 1.07)
Readmission length of stay in days	1.21 (0.68, 1.75)	1.37 (0.84, 1.89)	1.22 (0.69, 1.75)	1.24 (0.70, 1.77)
Readmission cost in $	19843.72 (11990.18, 27697.27)	8394.25 (3808.49, 12980.01)	10419.06 (5950.01, 14888.12)	19807.19 (12172.73, 27441.65)

Model 1: Fragmentation (primary exposure), Age, Sex, Insurance, Zip Income Quartile, Elixhauser Mortality Risk Score, Index admission length of stay, Index admission hospital cost
Model 2: Fragmentation (primary exposure), Model 1 covariates, Major Diagnostic Category
Model 3: Fragmentation (primary exposure), Model 2 covariates Hospital Bedsize * Hospital Control/Ownership * Hospital Teaching Status * Hospital Urban-Rural Designation
Reference group: Nonfragmented Non-DKA/HHS Readmission
Statistically significant outcomes highlighted in yellow

Table 6: Sensitivity Analysis: Index DKA admissions/DKA readmissions

Sensitivity Analysis: Index DKA Admissions/DKA Only Readmissions				
Outcome	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	0.76 (0.27, 2.11)	0.66 (0.24, 1.83)	0.67 (0.24, 1.88)	0.67 (0.24, 1.86)
Readmission LOS in days	0.002 (-0.204, 0.209)	0.09 (-0.11, 0.29)	0.09 (-0.11, 0.29)	0.09 (-0.11, 0.29)
Readmission cost in $	2184.15 (312.16, 4056.15)	1159.19 (-295.60, 2613.98)	1159.19 (-295.60, 2613.98)	1017.43 (-643.42, 2678.27)

Sensitivity Analysis: Index DKA Admissions/non-DKA Only Readmissions				
Outcome	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	1.06 (0.65, 1.73)	0.94 (0.57, 1.54)	0.92 (0.55, 1.51)	0.91 (0.55, 1.50)
Readmission LOS in days	1.15 (0.57, 1.74)	1.32 (0.74, 1.89)	1.16 (0.58, 1.74)	1.20 (0.61, 1.78)
Readmission cost in $	19201.99 (10625.72, 27777.26)	8136.65 (3317.25, 12956.04)	10405.31 (5660.66, 15149.95)	19526.34 (11065.31, 27987.37)

Model 1: Fragmentation (primary exposure), Age, Sex, Insurance, Zip Income Quartile, Elixhauser Mortality Risk Score, Index admission length of stay, Index admission hospital cost
Model 2: Fragmentation (primary exposure), Model 1 covariates, Major Diagnostic Category
Model 3: Fragmentation (primary exposure), Model 2 covariates Hospital Bedsize * Hospital Control/Ownership * Hospital Teaching Status * Hospital Urban-Rural Designation
Reference group: Nonfragmented DKAReadmission
Statistically significant outcomes highlighted in yellow

Table 7: Sensitivity Analysis: Index HHS admissions/HHS readmissions

Sensitivity Analysis: Index HHS Admissions/HHS Only Readmissions				
Outcome	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	> 999.99 (219.68, > 999.99)	> 999.99 (168.245, > 999.99)	> 999.99 (172.82, >999.99)	>999.99 (171.44, >999.99)
Readmission LOS in days	0.16 (-1.37, 1.69)	0.35 (-1.07, 1.77)	0.35 (-1.07, 1.77)	0.18 (-1.35, 1.71)
Readmission cost in $	9094.84 (-7174.02, 25363.71)	8239.12 (-2250.06, 18728.30)	8221.62 (-2266.94, 18710.18)	8156.80 (-8495.78, 24809.38)

Sensitivity Analysis: Index HHS Admissions/non-HHS Only Readmissions				
Outcome	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	0.73 (0.45, 1.18)	0.64 (0.40, 1.04)	0.64 (0.39, 1.04)	0.63 (0.39, 1.03)
Readmission LOS in days	1.12 (0.54, 1.69)	1.20 (0.63, 1.77)	1.03 (0.47, 1.59)	0.98 (0.42, 1.53)
Readmission cost in $	18527.61 (9387.69, 27667.53)	6951.17 (2364.23, 11538.11)	7926.84 (3349.25, 12504.43)	15963.55 (7448.46, 24478.63)

Model 1: Fragmentation (primary exposure), Age, Sex, Insurance, Zip Income Quartile, Elixhauser Mortality Risk Score, Index admission length of stay, Index admission hospital cost
Model 2: Fragmentation (primary exposure), Model 1 covariates, Major Diagnostic Category
Model 3: Fragmentation (primary exposure), Model 2 covariates Hospital Bedsize * Hospital Control/Ownership * Hospital Teaching Status * Hospital Urban-Rural Designation
Reference group: Nonfragmented HHS Readmission
Statistically significant outcomes highlighted in yellow

Table 8: Sensitivity Analysis: Index DKA/HHS Admissions/Myocardial Infarction (MI) readmissions

Sensitivity Analysis: Index DKA/HHS Admissions/Myocardial Infarction Readmissions				
Outcome	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	>999.99 (>999.99, >999.99)	>999.99 (>999.99, >999.99)	>999.99 (>999.99, >999.99)	>999.99 (>999.99, >999.99)
Readmission LOS in days	1.89 (-0.888, 4.66)	1.42 (-1.52, 4.37)	1.42 (-1.52, 4.37)	2.24 (-0.53, 5.01)
Readmission cost in $	43115.28 (-2376.55, 88607.11)	22467.93 (-9160.98, 54096.84)	22467.93 (-9160.98, 54096.84)	48297.82 (-1801.42, 98397.06)

Sensitivity Analysis: Index DKA/HHS Admissions/Non-Myocardial Infarction Readmissions				
Outcome	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	0.67 (0.45, 0.98)	0.60 (0.41, 0.89)	0.62 (0.42, 0.92)	0.50 (0.41, 0.62)
Readmission LOS in days	0.74 (0.44, 1.04)	0.84 (0.55, 1.13)	0.60 (0.32, 0.88)	0.60 (0.32, 0.89)
Readmission cost in $	12239.80 (8051.49, 16428.11)	5177.50 (2691.85, 7663.15)	5812.55 (3373.69, 8251.41)	9559.42 (5708.95, 13409.89)

Model 1: Fragmentation (primary exposure), Age, Sex, Insurance, Zip Income Quartile, Elixhauser Mortality Risk Score, Index admission length of stay, Index admission hospital cost
Model 2: Fragmentation (primary exposure), Model 1 covariates, Major Diagnostic Category
Model 3: Fragmentation (primary exposure), Model 2 covariates Hospital Bedsize * Hospital Control/Ownership * Hospital Teaching Status * Hospital Urban-Rural Designation
Reference group: Nonfragmented MI Readmission
Statistically significant outcomes highlighted in yellow

Table 9: Sensitivity Analysis: Index DKA/HHS admissions/Sepsis readmissions

Sensitivity Analysis: Index DKA/HHS Admissions/Sepsis Readmissions				
Outcome	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	0.82 (0.19, 3.56)	0.95 (0.17, 5.47)	1.00 (0.18, 5.59)	0.98 (0.17, 5.50)
Readmission LOS in days	-1.45 (-4.68, 1.78)	-0.69 (-3.47, 2.08)	-0.65 (-3.44, 2.15)	0.12 (-2.47, 2.71)
Readmission cost in $	30271.16 (-26931.93, 97474.24)	34594.67 (-29260.60, 98449.95)	35910.02 (-28188.21, 100008.35)	43157.85 (-27694.92, 114010.61)

Sensitivity Analysis: Index DKA/HHS Admissions/Non-Sepsis Readmissions				
Outcome	Unadjusted	Model 1	Model 2	Model 3
In-Hospital Mortality (readmission)	0.72 (0.49, 1.07)	0.64 (0.43, 0.96)	0.66 (0.45, 0.99)	0.66 (0.44, 0.98)
Readmission LOS in days	0.77 (0.48, 1.07)	0.87 (0.58, 1.16)	0.63 (0.36, 0.91)	0.64 (0.35, 0.92)
Readmission cost in $	12389.27 (8236.28, 16542.27)	5168.93 (2707.96, 7629.90)	5739.18 (3339.54, 8138.83)	9719.89 (5894.04, 13545.74)

Model 1: Fragmentation (primary exposure), Age, Sex, Insurance, Zip Income Quartile, Elixhauser Mortality Risk Score, Index admission length of stay, Index admission hospital cost
Model 2: Fragmentation (primary exposure), Model 1 covariates, Major Diagnostic Category
Model 3: Fragmentation (primary exposure), Model 2 covariates Hospital Bedsize * Hospital Control/Ownership * Hospital Teaching Status * Hospital Urban-Rural Designation
Reference group: Nonfragmented Sepsis Readmission
Statistically significant outcomes highlighted in yellow

Chapter 7: References

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