Predictors of 30-day Readmissions After Cardiac Surgery

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Abstract

Readmissions after cardiac surgery can have a detrimental impact on patient outcomes and the facility's finances. Identifying patients at risk for 30-day readmission can lead to improved patient outcomes and prevent readmissions through close follow-up and monitoring after discharge. A retrospective, case-controlled research study was conducted at Carilion Roanoke Memorial Hospital (CRMH) to: (1) identify the predictive factors of 30-day readmissions after discharge from cardiac surgery, and (2) investigate effectiveness of the currently used risk-stratification scoring systems such as the LACE plus score, the Society of Thoracic Surgeons (STS) mortality risk score, or the STS predicted risk of morbidity and mortality risk score to predict 30-day readmissions in this population. Of 227 patients in the study, 22 patients (9.69%) were readmitted within 30 days of discharge. This study observed that female gender (p=0.04), history of congestive heart failure (CHF) (p=0.01), extended cardiopulmonary bypass (CPB) time ($p < 0.05$), decreased hematocrit during hospitalization (p= 0.03), coagulopathy, anemia, heparin-induced thrombocytopenia and thrombosis (HITT), positive anti-platelet factor 4 (PF4)/heparin antibodies (p= 0.02), necessity of postoperative hemodialysis (HD) alone or with continuous renal replacement therapy (CRRT) (p=0.03 and p=0.03, respectively), and need for outpatient HD at time of discharge (p=0.01) were associated with 30-day readmission after cardiac surgery. This study could not discover the predictability of the LACE+ score for 30-day readmissions; however, a higher STS predicted risk of morbidity and mortality score was associated with 30-day readmissions (p= 0.03). Study findings suggest patients who are female, longer CPB time, lower hematocrits, history of CHF, coagulopathy, anemia, HITT, positive PF4, require HD during hospitalization or need HD at time of discharge may benefit from close

monitoring and earlier follow-up with the cardiothoracic provider post discharge after cardiac surgery to further decrease hospital readmissions within 30 days of discharge.

Dedication

I dedicate this work to my family. To my loving husband, Grant, you have been my rock throughout this entire process. Your unwavering love and support gave me encouragement when I needed it most. I am so blessed to have you by my side. Your sacrifices do not go unnoticed. Thank you for all that you have done and continue to do for me each and every day. To my parents, thank you for the unconditional love and always encouraging me to do my best. You taught me the values of hard work and dedication and for that I am forever grateful. To my late grandmother, Shirley Irby, you inspired me to live life to the fullest. Thank you for always supporting my dreams and pushing me to be the best version of myself. I will forever cherish the life lessons of leadership, fairness, and honesty you taught me. To my late grandparents, Thomas and Edith Milton, your devotion to family and compassion to those around you is something I will always cherish. Your teachings guided me through this program and helped me focus on what matters most. You all have impacted my journey and I wouldn't be where I am without each of you.

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Chapter 1: Introduction

Achieving reduction in hospital readmissions is a common goal for many healthcare systems. The Centers for Medicare and Medicaid Services (CMS) publicly report risk-standardized readmission rates (RSRR) for certain diseases and will eventually progress to enforcing reduced reimbursement payments for healthcare facilities with excessive readmission rates (Bergethon et al., 2016; Kripalani, Theobald, Anctil, & Vasilevskis, 2014). The Hospital Readmissions Reduction Program (HRRP), a product of the Affordable Care Act (ACA), authorizes CMS to reduce payment to hospitals with high readmission rates for medical conditions including heart failure (HF), pneumonia, acute myocardial infarction, chronic obstructive pulmonary disease (COPD), and stroke (Kripalani et al., 2014; U.S. Centers for Medicare & Medicaid Services [CMS], n.d.). Hospitals with unplanned readmissions after procedures such as coronary artery bypass graft (CABG), hip/knee replacement, and colonoscopy are also being penalized by CMS with reduced payments (CMS, n.d.). Iribarne et al. (2014) report that facilities with excessive 30-day readmission rates for any of the above-mentioned procedures may endure penalties ranging from 0.01%- 1% of Medicare revenue.

While hospital systems would like to avoid penalties associated with readmissions, patient outcomes remain a top priority. Evidence shows early readmission after discharge leads to poorer patient outcomes (Espinoza et al., 2016). Cardiac surgery patients have demonstrated high and diverse 30-day readmission rates with readmissions ranging from seven percent to twenty percent (Espinoza et al., 2016; Iribarne et al., 2014). Reducing readmission rates after cardiac surgery is essential to improvements in quality of care and overall patient outcomes in the cardiac surgery population (Iribarne et al., 2014). To achieve this overarching goal, all factors predisposing cardiac surgery patients to early readmissions within 30-days of discharge should be identified. Identification of risk factors allows providers the ability to recognize high risk patients earlier and implement targeted interventions to reduce readmissions.

In 2016, Carilion Roanoke Memorial Hospital, an acute care facility in southwest Virginia, performed approximately 500 cardiac surgery cases (Virginia Health Information [VHI], 2018b). This case number is considered a mid-high case category according to VHI. VHI indicated that this facility's 30-day readmission rating after any cardiac surgery was 9.88% and 8.33% for all cardiac surgery and CABG-only surgery respectively (VHI, 2018a). This figure is higher than the average readmission rates for hospitals in Virginia, where readmission rates of 7.17% and 6.64% for all cardiac surgery patients and CABG-only patients respectively are reported (VHI, 2018a). According to the Centers for Medicare and Medicaid Services (CMS) database (n.d.), CRMH had an average 15.5% readmission rate after CABG procedure during 2013-2016 (range, 12.5%-19%). This is higher than the average national readmission rate after CABG procedure (13.8%) (CMS, n.d.).

Nurse practitioners and physician assistants, as part of the cardiac surgery discharge team, currently use recommendations from the Virginia Cardiac Services Quality Initiative (VCSQI) to identify post-CABG patient risk for readmission at the time of discharge (Quader, Cox, Whaley, & Fonner, 2017). This protocol provides patient descriptors that identify patients at increased risk for readmission after cardiac surgery. Risk factor descriptors such as 'elderly' and 'postoperative complications' (Quader et al., 2017) leave room for discharging provider interpretation and are not necessarily objective measurements.

Case managers, as part of the discharge team, use the LACE Plus (LACE+) scoring system to predict readmission risk for post-cardiac surgery patients. The LACE+ score is calculated using the (L) length of hospital stay, (A) acuity of admission, (C) comorbidity, and (E) emergency department utilization in the 6 months prior to admission. LACE+ also considers patient demographic information, conditions and procedures performed during each admission, the number of urgent or elective admissions in the previous year, presence of change in level of care, and facility designation as a teaching facility or not (van Walraven, Wong, & Forster, 2012). Lack of effective readmission predictors will result in delay of post-discharge follow-up and increase risk of readmission.

Purposes of the Study

This study, as part of a quality improvement initiative, aimed to primarily (1) identify the predictive factors of 30-day readmissions after discharge from cardiac surgery. A secondary purpose of this study is to (2) investigate effectiveness of the currently used of the LACE+ score during hospitalization in predicting 30-day readmissions for adult cardiac surgery patients..

Prior to implementation of the study, a comprehensive literature review was conducted to identify risk factors associated with 30-day readmission rates among patients discharged after isolated Coronary Artery Bypass Graft surgery (CABG), isolated heart valve surgery (HVS), combination CABG and heart valve surgery, and aortic dissections or root surgery. In addition, scoring systems used to predict readmission likelihood were identified. Identified risk factors for 30-day readmission were categorized into demographic, comorbidity, hospital course, and procedural factors.

Chapter 2: Literature Review

Search Strategy

Search engines included databases MEDLINE, CINAHL (EBSCOHost), Cochrane Database of Systematic Reviews, and Trip medical database. Keywords included “predictors”, “readmissions”, “open heart surgery”, “cardiac surgery”, “risk factors”, and “30-days”. Focused inclusion criteria included target populations of traditional cardiac surgery consisting of isolated CABG, isolated HVS, and combination CABG/HVS. Literature review included full-text articles published between 2008 and 2018 that reported readmission data including but not limited to 30-days post-surgery and articles describing risk factors for readmission after cardiac surgery. Articles were excluded if published in a language other than English. Additional manuscript exclusions included subjects under 18 years of age, current clinical trials, and minimally invasive cardiac surgical approaches. Methodology of the literature review is summarized in a decision tree model in Appendix A.

To produce the most relevant search Boolean search phrases were combined. For example, "open heart surgery or cardiac surgery" was used in the same search box to produce the most relevant articles. The phrases "open heart surgery", "coronary artery bypass graft surgery" and "heart surgery" were interchangeable synonyms for "cardiac surgery" and prompted the most results in each database. "Predictors of" was placed prior to "readmission" to identify articles that described potential risk factors for readmissions after cardiac surgery. Using the above-mentioned key words, a total of 637 articles were identified from MEDLINE, CINAHL (EBSCOHost), Cochrane Database of Systematic Reviews, and Trip medical database. CINAHL yielded a total of 55 articles from which ten were chosen for further reading. Using identical phrases, the MEDLINE database produced 154 articles, with six duplicate articles. A total of 147 articles were screened and 27 were selected for closer review. The search phrases elicited 428 articles from the Trip medical database and 16 were chosen for literature analysis.

After applying inclusion and exclusion criteria, 13 articles remained and were included in the literature review. These articles included: one systematic review, two prospective cohort studies, and ten retrospective analyses. Summaries of individual studies is found in Appendix B and level of evidence for individual studies may be found in Appendix C. In the retrospective studies, data was gathered through a combination of patient chart review along with state and national database statistics. Seven articles included discussion on all types of cardiac surgery, five articles were limited to strictly CABG surgery, and one article limited discussion to HVS.

A variety of preoperative, intraoperative, and postoperative risk factors were identified through this literature review and may be categorized as patient, clinical, or procedural factors for study considerations.

Demographic Factors

Identified significant risk factors for patient readmission identified in literature included female gender and age (Hannan et al., 2011; Iribarne et al., 2014; Kripalani et al., 2014; Li, Amstrong, Parker, Danielsen, & Romano, 2012; Redžek et al., 2015; Shehata et al., 2013; Slamowicz et al., 2008; Sun et al., 2008). Studies reported adults over the age of 65 years were most likely to be readmitted after cardiac surgery (Hannan et al., 2011; Li et al., 2012; Shirzad et al., 2010; Slamowicz et al., 2008). In the systematic review by Fasken, Wipke-Tevis, and Sagehorn (2001), female gender, race other than Caucasian–especially African-American, and lower socioeconomic status were predominant risk factors for readmission in the post-cardiac surgery population. Unfortunately, in this analysis study cohorts were predominately male and many of the risk factors identified were non-modifiable. Iribarne et al. (2014) and Shirzad et al. (2010) included predominantly male samples which indicated a possible gap in knowledge regarding female patients who undergo cardiac surgery.

Comorbidity Factors

A systematic review by Fasken et al. (2001) reported presence of congestive heart failure (CHF) and Chronic Obstructive Pulmonary Disease (COPD) as predictors for 30-day readmission in post-cardiac surgery patients. Similarly, several studies observed the presence of comorbidities including diabetes mellitus (DM), COPD, CHF, and increased creatinine/renal failure (RF) to be associated with 30-day readmission rates in post-cardiac surgery patients (Hannan et al., 2011; Iribarne et al., 2014; Kripalani et al., 2014; Li et al., 2012; Redžek et al., 2015; Shehata et al., 2013; Slamowicz et al., 2008; Sun et al., 2008).

Hospitalization-Course Clinical Factors

Several studies discussed the role of hemoglobin and hematocrit in readmission risk. Authors identified a protective value of higher hemoglobin and hematocrit levels; additionally, hemoglobin and hematocrit levels were discussed in relation to the number of blood products received during hospitalization (Iribarne et al., 2014; Pack et al., 2016; Shehata et al., 2013; Sun et al., 2008). Another major risk factor identified in the literature reviewed was compromised ventricular function. Several researchers found that reduced right ventricular ejection fraction (RVEF) and left ventricular ejection fraction (LVEF) contributed to an increased risk for readmission after cardiac surgery (Hannan et al., 2011; Lella et al., 2015; Li et al., 2012; Maniar et al., 2014; Shehata et al., 2013).

Surgical and medical complications from cardiac surgery/procedures were also identified as a major risk factor for readmission (Espinoza et al., 2016; Hannan et al., 2011; Iribarne et al., 2014; Li et al., 2012; Pack et al., 2016; Redžek et al., 2015; Shirzad et al., 2010). Arrhythmias, heart failure/volume overload, and infection were identified as primary diagnoses for readmission at less than 30 days and greater than or equal to 30 days in post-cardiac surgery patients (Iribarne et al., 2014, p. 1277; Hannan et al.,2011; Pack et al., 2016; Redžek et al. 2015). Additionally, patients with postoperative atrial fibrillation had significant risk for readmission after cardiac surgery (Espinoza et al., 2016; Li et al., 2012; Shirzad et al., 2010).

Extended hospital length of stay (LOS) and intensive care LOS, also increased the likelihood of readmission after cardiac surgery (Fasken et al., 2001; Hannan et al., 2011; Pack et al., 2016; Slamowicz et al., 2008; Sun et al., 2008).

Procedural Factors

Authors reported that type of cardiac surgery procedures also influence 30-day readmission rates. Iribarne et al. (2014) reported patients who received combination CABG and valve surgery or who underwent left ventricular assist device/transplant surgery had the highest significant hazard ratio for readmission at 1.52 and 3.36 respectively (p. 1278). Conversely, Pack et al. (2016) identified patients who underwent dual valve surgery had the highest risk for readmission at 30 days.

Length of surgery and cardiopulmonary bypass (CPB) time were also observed as a significant readmission risk after cardiac surgery (Iribarne et al., 2014). Iribarne et al. noted a longer length of surgery carried a higher hazard ratio (HR) of 1.15 with a 95% confidence interval (CI) of 1.10-1.20 (Iribarne et al., 2014, p. 1278).

Readmission Prediction Scoring Systems for Cardiothoracic Surgical Patients

LACE-plus scoring system. Historically, this predictive LACE index scoring system was developed to assess readmission risk for acute coronary syndromes and cancer diagnoses (Teh & Janus, 2018). Differently, the LACE Plus (LACE+) scoring system was modified to more accurately predict readmission risk in medical and surgical populations (van Walraven et al., 2012). It is calculated from (L) length of hospital stay, (A) acuity of admission , (C) comorbidity and (E) emergency department utilization in the 6 months prior to admission. It also considers patient demographic information, conditions and procedures performed during hospitalization, number of urgent or elective admissions in the previous year, presence of change in level of care, and facility designation as a teaching facility or not (van Walraven et al., 2012). A higher value in this scoring system indicates a greater risk for 30-day readmission or 30-day death (van Walraven et al., 2012).

The LACE+ index was internally validated in acute care hospitals for medical and surgical populations, however, the specific surgical populations were not identified in the study (van Walraven et al., 2012). In van Walraven et al's study, the C statistic for the LACE+ index was 0.771, which is highly discriminative in predicting and correlating 30-day death or readmissions. As mentioned by van Walraven et al. (2012), further studies are needed to determine if this scoring method accurately predicts readmissions in specific surgical patients or if another scoring method should be utilized in these patients.

Garrison, Robelia, Pecina, & Dawson (2017) investigated the predictability of LACE+ index in orthopedic surgery, cardiology, internal medicine, trauma, and critical care patients in their cohort study (Garrison et al., 2017). Garrison et al. compared multiple readmission risk classifiers, including the LACE+ and original LACE indexes and concluded that both had similar discriminative ability in predicting 30-day readmissions with c-statistics of 0.66 and 0.68 respectively. Again, it is unclear if cardiac surgery patients were placed into one of the five patient groups mentioned earlier (Garrison et al., 2017).

Two studies showed the LACE+ scoring system to be relevant in both medical and surgical patient populations. However, it is unclear whether either study included cardiac surgery patients (van Walraven et al., 2012; Garrison et al., 2017). Currently studies validating the LACE+ scoring system and its predictability of readmission rates in cardiothoracic surgical patients are lacking. Also, the LACE+ index carries a concern about real time applicability due to the length of stay component not being calculated until time of discharge (Teh & Janus, 2018), as discharge planning typically occurs concurrently during hospitalization.

Espinoza-Readmission Prediction Scoring System. Efforts to create and utilize an objective scoring system to identify high risk post-cardiac surgery patients is imperative to optimize patient outcomes. Espinoza et al. (2016) developed such a system to predict 30-day readmission risk in patients undergoing cardiac surgery. In this study, the authors identified patient and surgical characteristics associated with increased readmissions. In a sample of 2,529 patients, Espinoza et al. (2016) identified preoperative, intraoperative, and postoperative variables that placed patients at higher risk for 30-day readmissions. Five variables including DM, preoperative hematocrit (HCT), CPB time in minutes, highest glycemic level during hospitalization (> 200 mg/dL) and postoperative atrial fibrillation (AF) were used in the final scoring system (Espinoza et al., 2016). A numerical score out of six possible points was calculated based on these variables. A higher score indicated a greater risk of readmission in 30 days. CPB time greater than 100 minutes was the most significant risk factor for readmission and carried a weight of two points in the scoring model (Espinoza et al., 2016). Espinoza et al. (2016) validated this scoring system in cohort of patients that included all genders, ages, and different types of cardiac surgery. The validation of the model occurred at a single center that performed about 500 cardiac surgeries per year (Espinoza et al., 2016). The authors acknowledge that "the frequency of readmission at each score level in the validation set fell within the 95% confidence interval" (Espinoza et al., 2016, p. 2), indicating predictability of the scoring system's validity at all score levels of early readmission.

Pack-Readmission Prediction Scoring System. Pack et al. (2016) created a scoring nomogram specifically for heart valve surgery patients as an objective measure to identify patients at risk for 30-day and 90-day readmission. This scoring system differed from Espinoza et. al (2016) in that it considered LOS, admission type, end-stage renal disease, blood product received, and procedure type (Pack et. al., 2016) as the most predictive indicators in risk stratification in heart valve surgery patients. This model provided an objective score for readmission, but also estimates likelihood of readmission based on the score. The scoring system has a total of 273 points with higher points indicating a higher chance percentage of readmission (Pack et al., 2016). This model was validated in only heart valve surgery patients and maintained a C-statistic of 0.65 (Pack et al., 2016). However, this study has a limitation because this predictive model was only validated for readmissions at three months post-discharge in heart valve surgery (Pack et al., 2016).

Literature Summary

This literature review yielded information about demographic, comorbidity, hospital course, and procedural factors associated with 30-day readmissions in the adult cardiac surgery patient population. A summary of the common risk factors associated with 30-day readmission in post-cardiac surgery patients is shown in Appendix D. Recurring identified risk factors included age greater than 60 years, female gender, comorbidities of CHF, DM, or RF, longer LOS, and dysrhythmias, especially the presence of postoperative atrial fibrillation. Awareness of these risk factors in adult cardiac surgery patient population potentially estimates predisposition of readmission within 30 days after cardiac surgery and is critical to improving patient outcomes especially at time of discharge. As noted by Pack et al. (2016), some risk factors are modifiable, and interventions may be incorporated into the patient's pre-discharge care to prevent readmission. Interventions focused on modifying risk factors included avoiding unnecessary blood product transfusion and/or making sure patients receive anti-dysrhythmic medications at discharge. Utilizing evidence from the literature is necessary to identify prevalent risk factors for readmission specific to clinical settings and targeted patient populations. Once specific risk factors are identified, interventions can then be tailored to the patient population.

In clinical practice, correlating patient risk factors with an objective scoring system for readmission can help practitioners identify high risk patients and allow for early interventions to prevent readmissions (Espinoza et al., 2016). While the scoring model created by Espinoza et al. (2016) has was only validated in one center, it was conducted in a variety of cardiac surgery patient cohorts. This tool accurately identified patients at high risk for readmission after cardiac surgery. This scoring model may benefit future practice at the study center if the LACE+ index is proven ineffective for post-cardiac surgery populations. The scoring model developed by Pack et al. (2016) may be beneficial when looking at ways to decrease readmissions at three months post discharge, however, current practice focuses on reducing readmissions at 30-days post-discharge after cardiac surgery; in the same reason Pack et al.'s (2016) scoring system requires additional validation to see if the scoring system is effective to predict the readmission for all cardiac surgical procedures as it had only been validated in heart valve surgery patients.

Chapter 3: Study Methods

In effort to identify the prevalent risk factors which increased adult cardiac surgery patients' 30-day readmission rate at CRMH, a retrospective case control study was performed through retrospective chart reviews and inspection of information from the Society of Thoracic Surgeons (STS) national database.

A 30-day readmission is defined as all cause readmission within 30-days of discharge after the cardiac surgical procedure. This study aims to: (1) identify risk factors of 30-day readmission after cardiac surgery and (2) determine the predictability of LACE+ score for 30-

day readmission after cardiac surgery. Patients who underwent cardiac surgery at CRMH between July 1, 2017 and December 31, 2017 and survived to discharge were placed into two groups: those readmitted within 30-days of discharge (30-day readmission group, RA group) and those who were not readmitted within 30-days of discharge (Non-RA group).

Study Setting

The setting for the study is CRMH in Roanoke, Virginia. CRMH is an acute care facility center located in Southwest Virginia, a part of the Carilion Clinic health care system. Carilion Clinic is a not-for-profit health care organization providing care to almost one million Virginians (Carilion Clinic, 2018). As mentioned previously, CRMH performs approximately 500 cardiac surgery cases per year (VHI, 2018b).

Study Subjects

The study's patient population included adult patients over 18 years of age who underwent cardiac surgery between July 1, 2017 to December 31, 2017. Cardiac surgical procedures included in the study were isolated CABG, isolated heart valve surgery, combinations of CABG/heart valve surgery, and aortic surgery. Patients were excluded if a minimally invasive method of cardiac surgery was used and/or if a patient died prior to the discharge from the hospital. The study was approved by Carilion Medical Center's Institutional Review Board with a reciprocal agreement from Radford University's Institutional Review Board.

Study Procedures, Data Collection and Data Security

Approval from Carilion Medical Center and Radford University's Institutional Review Boards (IRB) was obtained prior to accessing medical records. This study was deemed to carry minimal risk to the study subjects. Although researchers collected the minimum necessary personal health information (PHI) to access to medical records, this carried a risk of PHI data breech.

Study data was collected, managed and stored using the REDCap (Research Electronic Data Capture) production environment created by Carilion Clinic (Harris et al., 2009). REDCap is a secure, web-based instrument that allows a seamless workflow between data entry, data manipulation, and data export for statistical analysis (Harris et al., 2009). Access and interrogation of medical records was completed using a specific research account through the Health Analytics Research Team (HART) at Carilion. Patient information was de-identified prior to export for statistical analysis. In compliance with IRB regulations, any data not de-identified prior to being entered into REDCap (i.e. STS data) was stored on the Carilion password protected shared drive. Only de-identified data was shared with Radford University.

The STS national database was established in 1989 as a voluntary reporting system focusing on quality improvement and patient safety among participating cardiothoracic surgeons (The Society of Thoracic Surgeons [STS], 2018b). Study subjects, patients who underwent cardiac surgery at CRMH from July 1, 2017 through December 31, 2017, were identified within this database; every patient who undergoes cardiac surgery at CRMH is entered into it. Study variables classified as demographic and prehospital clinical data, in-hospital procedural and clinical data, and post-hospital data were primarily extracted from the STS database. Electronic medical record (EMR) reviews were subsequently performed for patients who met the inclusion criteria. The medical records of all patients who underwent cardiac surgery during the study's timeframe were retrospectively reviewed.

Study variables. Data obtained from the STS database included demographic data (patient age, gender, race), pre-hospital clinical data (body mass index [BMI], history of DM and CHF, and history of previous sternotomy surgery). In-hospital clinical data obtained from the EMR included urgency of cardiac surgery (elective, urgent, emergent), cardiac surgery procedure type, length of cardiopulmonary bypass time, use of cardiac device support, number of packed red blood cell (PRBCs) units received, highest postoperative serum creatinine level, use of continuous renal replacement therapy (CRRT), new CHF diagnosis during hospitalization, lowest hematocrit, LVEF, highest blood glucose greater than 200mg/dl, intensive care unit LOS, overall hospital LOS (surgery to discharge), unplanned reoperation, unplanned readmission to ICU, postoperative complications including post-surgical AF and cardiac arrest, and other post-surgical complications (See Table 1).

Post-hospitalization data collected included occurrence of 30-day readmission, readmission diagnosis, need for outpatient hemodialysis (HD) at discharge, discharge disposition (home, home with home health, inpatient rehabilitation, skilled nursing facility, other, expired), and timing of clinic postoperative follow-up (within 2-weeks-yes/no). Some of the data was additionally extracted from the patient's EMR (See Table 1).

Table 1 *Major Study Variables*

Pre-Hospitalization Variables

• **Patient Demographics:**
  ○ Age
  ○ Gender
  ○ Race
• **Co-Morbidities:**
  ○ BMI
  ○ DM
  ○ CHF
  ○ Previous sternotomy surgery

In-hospitalization Data

• **Surgical Procedures**
  ○ Cardiac surgery procedure type
  ○ Urgency of procedure/surgery
  ○ Length of CPB time

- **Overall Clinical Data**
    - Use of cardiac support device
    - HCT
    - EF%
    - Hyperglycemia
    - Renal Function (postoperative serum creatinine)
    - PRBCs received
    - LOS (ICU and surgery to discharge)
    - Unplanned re-operation
    - Use of CRRT postoperatively
    - New CHF diagnosis
    - Postoperative AF
    - Postoperative cardiac arrest
    - Unplanned readmission to ICU
    - Other post-surgical complications*

Post-Hospitalization Data

- Readmission within 30-days of discharge
- Readmitting diagnosis
- Need for outpatient HD at discharge
- Discharge disposition
- Timing of clinic postoperative follow-up

Predicted Scoring Systems

- LACE+ score
- STS predicted risk of mortality score
- STS predicted risk of morbidity and mortality score

*Other post-surgical complications include: Renal-Dialysis Required, Deep Sternal Infection / Mediastinitis, Infection-Conduit Harvest, Infection-Cannulation Site, Sternotomy Issue, Sepsis, Neurological-Stroke Perm, Transient ischemic attack (TIA), Encephalopathy, Coma/Unresponsive State, Paralysis, Ventilator Prolonged, Pneumonia, Venous Thromboembolism-VTE, Vascular-Iliac/Femoral Dissect, Vascular-Acute Limb Ischemia, Mechanical Assist Device Related Complication, Rhythm Disturbance Requiring Permanent Device, Aortic Rupture, Aortic Dissection, Anticoagulation Event, Gastrointestinal Event, Liver Dysfunction or Failure, Multi-System Failure, Pleural effusion, Pneumothorax (PNTX), increased chest tube output; Purulent sputum, bronchitis; Prolonged inotropic support; Coagulopathy, anemia, heparin-induced thrombocytopenia and thrombosis (HITT), positive anti-platelet factor 4 (PF4); Hemodynamic Instability, Dysphagia, Increased oxygen demand/need, Dysrhythmia other than atrial fibrillation, Wound issues, Urinary retention, Safety concerns, Required urgent cardiac catherization, Pericarditis, Medication Reaction, Radial artery occlusion/ulnar neuropathy

Postoperative complications variables were collected from the STS database as well as the retrospective chart review. In alignment with the STS definition, postoperative complications are defined as events that may pose a life threatening situation or potential long-term deficit, require pharmacological, surgical, or medical intervention, or increase LOS (STS, 2018a). During the chart review of patients, complications were gathered from the discharge summary. Complications collected through retrospective chart review were grouped by like-characteristics and body systems to minimize the number of related groups of variables. Pleural effusion, pneumothorax, and increased chest tube output were grouped together as these are similar in characteristics and interventions.

During the retrospective chart review, subjective discussion of variables existed. For the purposes of this study, hemodynamic instability was defined as a condition requiring vasoactive (antihypertensive and vasopressor) medications greater than 24 hours; including antihypertensives and vasopressors. Prolonged inotropic support differs from hemodynamic instability and is defined as needing inotropic support for greater than 24 hours or requiring inotropic medications to be restarted postoperatively. In the study the variable increased oxygen need was recorded as a postoperative complication if documented by the discharging provider or the diagnosis codes of pulmonary insufficiency or respiratory failure were found in the discharge summary. Pulmonary insufficiency is defined as needing a range of 6 to 12 liters of oxygen. Respiratory failure is defined as requiring greater than 12 liters of oxygen, use of BiPap, or reintubation. Safety concerns were captured as a complication if the patient required a sitter, had delirium or impulsivity postoperatively.

Two STS risk stratification scores, predicted risk of mortality score and predicted morbidity and mortality score, were extracted from the STS database. Each score was individually correlated with 30-day readmissions. The STS predicted mortality score is commonly used to predict the risk of mortality in patients who undergo cardiothoracic surgery, based on all patient deaths that occurred during hospitalization during the procedure, and even after discharge within 30 days of the procedure (The Society of Thoracic Surgeons [STS], n.d.) The predicted risk of mortality score delineates perioperative mortality into low risk (less than 4%) intermediate risk (4% - 8%), and high risk (greater than 8% to greater than 12%) (Vassileva et al., 2015).

STS also defines the predicted morbidity and mortality score as a composite endpoint score calculated from the predicted mortality score in addition to a score considering the complications of cardiac surgery including stroke, renal failure, prolonged ventilation greater than 24 hours, deep sternal wound infection, and reoperation (STS, n.d.). In line with the predicted risk of mortality score, this calculation gives a percentage as the final score and the higher the percentage, the higher the overall risk for mortality and/or morbidity (STS, n.d.).

The LACE+ score is used to predict the 30-day readmission rate in medical and surgical patients and was extracted from individual patients' EMRs. The LACE+ index uses an objective scoring system ranging from -2 to 90 points (Garrison et al., 2017) and had been utilized by the discharging team in this study's settings to help predict risk of readmissions after cardiac surgery and thus is available in individual medical records. Each component of the index carries a numeric value and the total of all values is the LACE+ score, where a higher value indicates a greater risk for 30-day readmission or 30-day death (van Walraven et al., 2012). The total LACE+ score is categorized into four groups: 0-28 (minimal risk), 29-58 (moderate risk), 59-78 (high risk), and 79-90 (highest risk) (Dermenchyan, 2017).

Statistical Analysis

The main purpose of this study was to identify specific risk factors of 30-day readmissions in patients undergoing cardiac surgery. Independent variables were categorized into pre-hospitalization data (patient demographic and clinical data), hospitalization data (surgical variables and overall clinical data) and post-hospitalization data. Continuous variables were recorded in mean and standard deviations while categorical variables were recorded as frequencies and percentages. The dependent variable, readmission within 30 days of hospital discharge, was measured as a nominal variable (yes or no) for individual patients and the 30-day readmission rates among all study participants were expressed through frequencies and percentages.

The differences between readmission (RA) group and non-RA group in pre-hospitalization, in-hospitalization, and post-hospitalization data were compared through t-testing for continuous variables and Fisher's Exact or Chi-Square testing for categorical or nominal variables, respectively. After significant variables were identified through p values less than 0.05, statistical analysis using logistic regression was conducted to correlate those predictive variables with 30-day readmissions and identify the best predictive models for risk of 30-day readmission for cardiothoracic surgical patients. Backward elimination and forward selection were both utilized to assess for the best fit model.

The secondary aim of this study was to evaluate correlation of the risk stratification scoring systems LACE+, the STS predicted risk of mortality score, and the STS predicted morbidity/mortality score with 30-day readmissions. This was completed concurrently with the logistic regression methods mentioned above. Statistical Analysis System (SAS) was used to perform all statistical analysis for this study.

Chapter 4: Study Results

A total of 249 patients underwent cardiac surgery at the study site from July 2017 to December 2017. Among those patients, nine minimally-invasive surgery patients were eliminated and 13 patients who died during their hospitalization were also eliminated. Therefore, a total of 227 patients who underwent cardiac surgery between July 1, 2017 and December 21, 2017 were included in the final analysis. Of those patients, 22 had hospital readmissions (RA) and 205 patients did not (non-RA).

Pre-Hospitalization Data (Refer to Table 2)

The mean age of all patients in this study was 64.66 years ± 11. About 65.64% of all patients were male, but no difference was found in the mean age between male and female. The primary races observed in this study included white (n=210, 92.92%), African American (n=14, 6.19%), Asian (n=1, 0.44%) and American Indian/Alaskan Native (n=1, 0.44%). The mean BMI of all patients was 29.68 ± 5.79. Among all patients, 90 (39.65%) and 48 (21.15%) patients had a history of DM and CHF, respectively.

Of the 227 patients included in the study, a total of 22 (9.69%) patients were readmitted within 30-days of hospital discharge. Between the readmission group (RA group) and non-readmission group (non-RA group), no difference was observed in mean age or race distribution. However, the gender distribution was different in the RA group and non-RA group. The RA group has similar distribution between males and females (45.5% vs. 54.6%); whereas, male patients were more dominant then female patients (67.8% vs. 32.3%) in the non-RA group.

A higher proportion of RA patients had a history of CHF then non-RA patients (45.45% in RA group vs. 18.54% in non-RA group, p=0.010). Differently, BMI and a history of DM were not statistically different between the two study groups (p=0.60 and p=0.56 respectively) (see Table 2).

Table 2. *Pre-hospitalization Patient Demographic and Clinical Data Comparison Between RA Group and Non-RA Group*

	All patients	30-Day Readmissions Group (RA Group)	No 30-Day Readmissions (Non-RA Group)	P value
	Frequency (%) or Mean ± SD (n = 227)	Frequency (%) or Mean ± SD (n = 22)	Frequency (%) or Mean ± SD (n = 205)	
Demographic Variables				
Mean age in years	64.66 ± 10.99	64.41 ± 10.97	64.68 ± 11.02	0.9118
Gender				
– Male	149 (65.64%)	10 (45.45%)	139 (67.80%)	0.0359*
– Female	78 (34.36%)	12 (54.55%)	66 (32.30%)	
Race				
– White	210 (92.92%)	19 (86.36%)	191 (93.63%)	0.1249
– Black/African American	14 (6.19%)	2 (9.09%)	12 (5.88%)	
– Hispanic/Latino/Spanish	0 (0%)	0 (0%)	0 (0%)	
– Asian	1 (0.44%)	0 (0%)	1 (0.49%)	
– American Indian/Alaskan Native	1 (0.44%)	1 (4.55%)	0 (0%)	
– Hawaiian/Pacific Islander	0 (0%)	0 (0%)	0 (0%)	
Comorbidity Variables				
BMI	29.68 ± 5.79	30.30 ± 29.61	29.61 ± 5.91	0.5997
DM	90 (39.65%)	10 (45.45%)	80 (39.02%)	0.5579

CHF	48 (21.15%)	10 (45.45%)	38 (18.54%)	0.0103*

*= P value <0.05

In-Hospitalization Data: Surgical Procedures (Refer to Table 3)

A total of 221 (97.36%) patients underwent their first cardiac surgical procedure during this study's timeframe while six (2.64%) patients had a history of previous cardiac surgery. Most patients (62.11%, n=141) underwent cardiac surgery electively, whereas 79 (34.8%) and seven (3.08%) patients underwent urgent or emergent procedures, respectively. A total of 139 patients (61.24%) underwent a surgical procedure that involved coronary artery bypass grafting (CABG): CABG only (n=128, 56.39%), aortic valve repair and CABG (n=9, 3.96%), and mitral valve repair and CABG (n=2, 0.88%). The next common cardiac procedures following those including a CABG were aortic valve replacements (AVR) (n=21, 9.25%), aortic dissection/ root procedures (n=18, 7.93%), and "other" procedures, which included any CABG or valve surgery that involved a MAZE procedure, patent foramen ovale (PFO) closures, left atrial appendage procedure (n=40, 17.62%). The mean length of CPB time during surgery was 102.85 minutes ± 48.

A majority of both RA patients (95.45%) and non-RA patients (97.6%) had undergone their first cardiac surgical procedure during the study period; a history of previous cardiac surgical procedure was proportionally the same for both study groups and was not found to be statistically significant (*p*=0.46). A majority of the RA patients (54.55%) and non-RA patients (62.93%) underwent an elective cardiac surgical procedure; no difference was noticed in the proportion of the procedure urgency status between two groups (*p*=0.41).

The proportion of different procedure types was similar between RA and non-RA groups. When the RA patients were compared to non-RA patients, CABG remained the majority procedure type in both groups (45.45% and 57.56% respectively, *p*=0. 28). Length of CPB time was statically significant between the two groups. RA patients had a longer CPB time of 122.1 minutes ± 59 than non-RA patients (100.7 minutes ± 46) (*p*< 0.05) (see Table 3).

Table 3. *In-Hospitalization Data: Surgical Procedures Comparison Between RA Group and Non-RA Group*

	All patients	30-Day Readmissions Group (RA Group)	No 30-Day Readmissions (Non-RA Group)	P value
	Frequency (%) or Mean ± SD (n =227)	Frequency (%) or Mean ± SD (n = 22)	Frequency (%) or Mean ± SD (n = 205)	
Surgical Variables				
History of previous surgery				
– First	221 (97.36%)	21 (95.45%)	200 (97.56%)	0.4614
– Repeat	6 (2.64%)	1 (4.55%)	5 (2.44%)	
Procedure Urgency Status				
– Elective	141 (62.11%)	12 (54.55%)	129 (62.93%)	0.4127
– Urgent	79 (34.8%)	10 (45.45%)	69 (33.66%)	
– Emergent	7 (3.08%)	0 (0%)	7 (3.41%)	
Procedure Type				
– CABG	128 (56.39%)	10 (45.45%)	118 (57.56%)	0.2765
– AVR	21 (9.25%)	4 (18.18%)	17 (8.29%)	0.1301
– Aortic dissection/root procedures	18 (7.93%)	1 (4.55%)	17 (8.29%)	1
– AVR, CABG	9 (3.96%)	1 (4.55%)	8 (3.9%)	1
– AVR, MVR	1 (0.44%)	0 (0%)	1 (0.49%)	1
– MV Repair	4 (1.76%)	0 (0%)	4 (1.95%)	1
– MV Repair, CABG	2 (0.88%)	0 (0%)	2 (0.98%)	1
– MVR	4 (1.76%)	1 (4.55%)	3 (1.46%)	0.3368
– MVR, CABG	0 (0%)	0 (0%)	0 (0%)	---
– Other	40 (17.62%)	5 (22.73%)	35 (17.07%)	0.5552
Length of CPB time	102.85 ± 47.66	122.1 ± 59.03	100.7 ± 45.94	0.0454*

*= P value <0.05

Overall Clinical Data During Hospitalization (Refer to Table 4)

Use of cardiac device support. Only eight patients out of 227 (3.52%) required cardiac device support postoperatively, including three (1.32%) patients requiring extracorporeal membrane oxygenation (ECMO), four (1.76%) patients requiring intra-aortic balloon counterpulsation (IABPs), and one (0.44%) patient requiring a ventricular support device. No patients in the RA group required cardiac device support. No statistical significance was found in the use of cardiac device support between the two cohorts (p=1.00).

New CHF Diagnosis and Left Ventricular Ejection Fraction Percent. Six patients (2.65%) had a new diagnosis of CHF postoperatively, although none of those patients were readmitted within 30 days after the discharge. No statistical significance was observed in the occurrence of new onset of CHF (0% in RA group and n=6, 2.94% in non-RA group, p = 1.00).

LVEF was delineated into 12 groups, with the majority of patients having an EF greater than 40 to 45% (88.11%). Only 18.19% (n=4) of the RA group and 11.23% (n=23) of the non-RA group had an EF less than 40 %. This variable was proportionally the same for both groups of patients and held no statistical significance (p= 0.406). The mean LVEF of all patients was 55.24 ± 11.15. The mean LVEF nearly identical in each group: 55.23 ± 13.23 among RA patients and 55.24 ± 10.95 among non-RA patients (p=0.995).

Hematocrit and blood products received. The mean HCT for all patients in the study was 26.21 ± 5.10 and patients received an average of 2.65 ± 3.32 PRBC units. Patients who were readmitted had a lower HCT (23.99 ± 4.46) compared to the patients who were not readmitted (26.45 ± 5.11) (p=0.03). However, there was not a statistically significant difference in the mean units of PRBCs received by the study groups (2.92 units ± 3.30 for RA patients and 2.59 units ± 3.35 for non-RA patients; p=0.75).

Renal function. The average highest serum creatinine of all patients was 1.21 ± 0.78. RA patients had a higher postoperative serum creatinine compared to non-RA patients not (1.68 ± 1.32 and 1.15 ± 0.68, respectively; p=0.08), although statistical significance was not observed at the alpha value of 0.05. Five patients (2.20%) required CRRT postoperatively. This was further divided into patients that required both CRRT and HD (n=3, 1.32%), patients who had CRRT only (n=2, 0.88%). No patient required HD only. A total of two patients (9.09%) in the RA group required CRRT compared to three patients (1.46%) of the non-RA group. No statistical difference was found in the proportion of patients who received postoperative CRRT HD between RA group and non-RA group (*p*= 0.08); however, when patients were divided by CRRT only, HD only, or both CRRT and HD, the RA group had a statistically significant higher portion (n=2, 9.09%) of patients who had both CRRT and HD than non-RA group (n=1, 0.49%) (*p*=0.03).

Hyperglycemia. A total of 97 (42.73%) patients had a blood glucose reading of greater than 200 mg/dl during hospitalization. Among those 97 patients, the mean blood glucose reading above 200 mg/dl was 269.65 mg/dl ± 80.68. There was not a statistically significant difference in the highest blood glucose reading in the RA groups compared to non-RA group (293.0 mg/dl ± 82.16 vs. 267.0 mg/dl ± 80.56; *p*= 0.337).

Unplanned ICU readmission or re-operation. In this study, unplanned reoperations in the cardiac surgery operating room (CSOR) were related to bleeding complications, valve dysfunction, or other complications in this study. Only 10 patients (4.41%) required an unplanned reoperation in the CSOR during the postoperative period with six patients (2.64%) undergoing reoperation for bleeding. No patients returned to the operating room (OR) due to valve dysfunction and four patients returned to the OR for other complications.

Of the six patients that returned OR for postoperative bleeding complications, none were readmitted within 30 days of discharge. A return to CSOR due to "other" complications was similar between groups (4.55% in RA group vs. 1.5% in the non-RA group, *p*= 0.34).

Seven patients (3.08%) who had moved to a progressive care unit postoperatively required unexpected readmission to the ICU. Unplanned readmissions to the ICU were similar (one patient [4.55%] in the RA group, and six patients [2.93%] in the non-RA group) (*p=0.*52).

Length of stay. The mean ICU LOS of the study sample was 78.24 hours ± 92. Although not statistically significant, RA patients had a clinically significant longer stay LOS in the ICU compared to non- RA patient (124.0 hours ± 148 vs. 73.33 hours ± 83.24, respectively), a difference of 50 hours (*p*=0.13).

For this study's purposes, hospital LOS (HLOS) was defined as the time frame from surgery to discharge. The overall mean HLOS was 7.70 days ± 7. Readmitted patients had a longer average HLOS than did non-readmitted patients (11.18 days ± 14 vs. 7.32 days ± 6). Although no statistically significant (*p*=0.21) this finding may hold clinic significance.

Table 4. *Overall Clinical Data During Hospitalization Comparison Between RA Group and Non-RA Group*

	All patients	30-Day Readmissions Group (RA Group)	No 30-Day Readmissions (Non-RA Group)	P value
	Frequency (%) or Mean ± SD (n =227)	Frequency (%) or Mean ± SD (n = 22)	Frequency (%) or Mean ± SD (n = 205)	
Overall Hospitalization Variables				
Use of cardiac device support				
– VAD	0 (0%)	0 (0%)	0 (0%)	----
– ECMO	3 (1.32%)	0 (0%)	3 (1.46%)	1.00
– IABP	4 (1.76%)	0 (0%)	4 (1.95%)	1.00
– Impella	1 (0.44%)	0 (0%)	1 (0.49%)	1.00
New CHF diagnosis	6 (2.65%)	0 (0.00%)	6 (2.94%)	1.00
Ejection Fraction				
– < 10%	1 (0.44%)	0 (0%)	1 (0.49%)	0.4064
– 10 – 15%	1 (0.44%)	0 (0%)	1 (0.49%)	
– 20 – 25%	6 (2.64%)	1 (4.55%)	5 (2.44%)	
– 25 – 30%	9 (3.96%)	3 (13.64%)	6 (2.93%)	
– 30 – 35%	5 (2.2%)	0 (0%)	5 (2.44%)	
– 35 – 40%	5 (2.2%)	0 (0%)	5 (2.44%)	
– 40 – 45%	20 (8.81%)	0 (0%)	20 (9.76%)	
– 45 – 50%	12 (5.29%)	0 (0%)	12 (5.85%)	
– 50 – 55%	32 (14.1%)	3 (13.64%)	29 (14.15%)	
– 55 – 60%	79 (34.8%)	8 (36.36%)	71 (34.63%)	
– 60 – 65%	54 (23.79%)	7 (31.82%)	47 (22.93%)	
– 65 – 70%	3 (1.32%)	0 (0%)	3 (1.46%)	
EF % (Highest End of Range) (Mean ± SD)**	55.24 ± 11.15	55.23 ± 13.23	55.24 ± 10.95	0.9947
HCT (lowest during hospitalization)	26.21 ± 5.10	23.99 ± 4.46	26.45 ± 5.11	0.0312*
Units of Packed Red Blood Cells received	2.65 ± 3.32	2.92 ± 3.30	2.59 ± 3.35	0.7485
Renal function (highest postop creatinine)	1.21 ± 0.78	1.68 ± 1.32	1.15 ± 0.68	0.0811
Use of CRRT postoperatively	5 (2.20%)	2 (9.09%)	3 (1.46%)	0.0750
– Both CRRT and Dialysis	3 (1.32%)	2 (9.09%)	1 (0.49%)	0.0342*
– Only CRRT	2 (0.88%)	0 (0%)	2 (0.98%)	1.00

– Only Dialysis	0 (0%)	0 (0%)	0 (0%)	----
Hyperglycemia	269.65 ± 80.68	293.0 ± 82.16	267.0 ± 80.56	0.3365
Unplanned readmission to ICU	7 (3.08%)	1 (4.55%)	6 (2.93%)	0.5151
Unplanned Return to CSOR				
– Bleeding	6 (2.64%)	0 (0%)	6 (2.94%)	1.00
– Valve dysfunction	0 (0%)	0 (0%)	0 (0%)	----
– Other	4 (1.80%)	1 (4.55%)	3 (1.50%)	0.3432
Length of stay (LOS)				
– Total intensive care LOS (Hours)	78.24 ± 92.19	124.0 ± 147.5	73.33 ± 83.24	0.1269
– Hospital LOS (surgery to discharge) (Days)	7.70 ± 6.91	11.18 ± 13.83	7.32 ± 5.63	0.2080

*= P value <0.05 **For this variable, we converted the LVEF categories to the highest end of each rang to calculate the mean LVEF

Postoperative Complications Data During Hospitalization (Refer to Table 5)

Post-surgical complications were divided into nine major groups: infections, neurological, respiratory, cardiovascular, peripheral vascular, hematologic, gastrointestinal, organ failure, and other. Of those complications, 25 individual complications were collected from the STS database and 15 were extracted from the EMRs retrospectively.

Table 5 provides the detailed list of complications and the frequency of each complication seen in both the RA and non-RA groups. Among all complications listed for this study, only postoperative coagulopathy, anemia, HITT, or positive PF4 and renal failure requiring dialysis were found to be significant factors influencing 30-day readmissions.

Postoperative infections. Occurrence of postoperative infections including deep sternal infection/mediastinitis, conduit harvest infection, cannulation site infections, sternotomy issues, and sepsis was collected for this study. No patients in either the RA group or the non-RA groups experienced any of the above-mentioned complications.

Neurological complications. A total of 10 patients (4.41%) in the sample experienced a neurological complication including: encephalopathy (n=7, 3.08%), stroke-ischemic (n=1, 0.44%), and stroke of undetermined type (n=2, 0.88%). Encephalopathy occurrence was similar (p=0.14) between groups with two patients (9.09%) in the RA group and five patients (2.44%) in the non-RA group. No other neurological complications were experienced by the RA patients.

Respiratory complications. 49 patients (21.59%) experienced an increased oxygen demand/need in the postoperative period requiring either (1) more than five liters of oxygen through nasal canula, (2) non-invasive ventilation via BiPAP, or (3) reintubation. Twenty patients (8.81%) experienced either a pleural effusion, pneumothorax or an increase in chest tube output postoperatively; 17 patients (7.49%) required prolonged mechanical ventilation (greater than 24 hours); and five patients (2.20%) had purulent sputum and/or bronchitis. No statistically significant difference was observed between RA and non-RA groups respiratory complications.

Cardiovascular complications. In the total sample, the most common cardiovascular complications included need for prolonged inotropic support (n=58, 25.55%), postoperative AF (n=56, 24.67%), hemodynamic instability (n=26, 11.45%) and dysrhythmia other than AF (n=12, 5.29%). The need for prolonged inotropic support was comparable between the two cohorts (n=6, 27.27% for RA and n=52, 25.37% for non-RA; $p= 0.80$). The rate of postoperative AF was nearly equal in both groups ($p=0.77$), with six RA patients (27.27%) experiencing AF postoperatively compared to 50 patients (24.39%) in the non-RA group. Similarly, no difference was found in the among the groups with hemodynamic instability and with dysrhythmia other than AF for both study groups ($p=0.73$ and $p=0.10$, respectively).

Peripheral vascular complications. In this study population, venous thromboembolism (VTE) (n=5, 2.20%) and radial artery occlusion or ulnar neuropathy (n=2, 0.88%) were the only peripheral vascular complications observed. One patient (4.55%) in the RA group had a VTE during the postoperative period compared to four patients (1.95%) in the non-RA group ($p=0.40$). Radial artery occlusion/ulnar neuropathy was proportionally the same between both groups (n=1, 4.55% for RA patients and n=1, 0.49% for non-RA patients; $p= 0.19$).

Hematological complications. 45 patients (19.82%) experienced postoperative complication of coagulopathy, anemia, heparin-induced thrombocytopenia and thrombosis (HITT), positive anti-platelet factor 4 (PF4)/heparin antibodies. There was a higher occurrence of this hematological complication among RA patients than non-RA patients (n=9, 40.91% in the RA group compared to n=36, 17.56% in the non-RA group; $p = 0.02$). A total of two patients (0.88%) experienced an anticoagulation event defined by STS as "patients that bleed, hemorrhage and /or suffer an embolic event related to anticoagulant therapy received post-op" (STS, 2018a). By this definition, RA patients experienced the STS defined anticoagulation event.

Gastrointestinal complications. Six patients (2.64%) experienced a GI event postoperatively and seven patients (3.08%) had complications related to dysphagia in the postoperative period. The occurrence of GI events and dysphagia were comparable among the two cohorts ($p > 0.05$).

Organ failure and other complications. Three patients (1.32%) required HD in the postoperative period. A statistically significantly higher proportion ($p = 0.03$) of the RA group (n=2, 9.09%) required HD postoperatively compared to the non-RA group (n=1, 0.49%). As mentioned above and shown in Table 4, these patients also required CRRT postoperatively and were transitioned to HD.

Others. Data collected on other postoperative complications included safety concerns (n=13, 5.73%), urinary retention (n=12, 5.29%), wound issues (n=8, 3.52%) and medication reactions (n=3, 1.32%). Postoperative safety concerns were proportionally the same for both RA patients (n=1, 4.55%) and non-RA patients (n=12, 5.85%) ($p = 1.00$). Similarly, the occurrence of postoperative wound issues, urinary retention or medication reactions were also found to be similar with no statistical significance between readmitted patients and non-readmitted patients (*p*>0.05).

Table 5. *Postoperative Complications Data During Hospitalization Comparison Between RA Group and Non-RA Group*

	All patients	30-Day Readmissions Group (RA Group)	No 30-Day Readmissions (Non-RA Group)	P value
	Frequency (%) or Mean ± SD (n =227)	Frequency (%) or Mean ± SD (n = 22)	Frequency (%) or Mean ± SD (n = 205)	
Post-Surgical Complications				
Post-op Infections				
Deep Sternal Infection / Mediastinitis**	0 (0%)	0 (0%)	0 (0%)	----
Infect-Conduit Harvest **	0 (0%)	0 (0%)	0 (0%)	----
Infect-Cannulation Site**	0 (0%)	0 (0%)	0 (0%)	----
Sternotomy Issue**	0 (0%)	0 (0%)	0 (0%)	----
Sepsis**	0 (0%)	0 (0%)	0 (0%)	----
Neuro-Stroke Permanent Injury				
Encephalopathy**	7 (3.08%)	2 (9.09%)	5 (2.44%)	0.1398
Stroke: Ischemic**	1 (0.44%)	0 (0%)	1 (0.49%)	1.00
Stroke: Undetermined Type**	2 (0.88%)	0 (0%)	2 (0.98%)	---
TIA**	0 (0%)	0 (0%)	0 (0%)	----
Coma/Unresponsive State**	0 (0%)	0 (0%)	0 (0%)	----
Paralysis**	0 (0%)	0 (0%)	0 (0%)	----
Respiratory Complications				
Increased oxygen demand/need	49 (21.59%)	6 (27.27%)	43 (20.8%)	0.5848
Pleural effusion, PNTX, increased CT output	20 (8.81%)	2 (9.09%)	18 (8.78%)	1.00
Vent Prolonged greater than 24 hours**	17 (7.49%)	3 (13.64%)	14 (6.83%)	0.2190
Purulent sputum, bronchitis	5 (2.20%)	2 (9.09%)	3 (1.46%)	0.0750
Pneumonia**	1 (0.44%)	0 (0%)	1 (0.49%)	1.00
Cardiovascular Complication				
Prolonged inotropic support	58 (25.55%)	6 (27.27%)	52 (25.37%)	0.8017
Postop atrial fibrillation**	56 (24.67%)	6 (27.27%)	50 (24.39%)	0.766
Hemodynamic Instability	26 (11.45%)	3 (13.64%)	23 (11.22%)	0.7246
Dysrhythmia other than Afib	12 (5.29%)	3 (13.64%)	9 (4.39%)	0.0978
Rhythm Disturbance Requiring Perm Device**	2 (0.88%)	0 (0%)	2 (0.98%)	1.00
Postoperative cardiac arrest**	2 (0.88%)	0 (0.00%)	2 (0.98%)	1.00
Required urgent cardiac catheterization	2 (0.88%)	0 (0%)	2 (0.98%)	1.00
Pericarditis	1 (0.44%)	0 (0%)	1 (0.49%)	1.00
Aortic Rupture**	0 (0%)	0 (0%)	0 (0%)	----
Aortic Dissection**	0 (0%)	0 (0%)	0 (0%)	----
Mechanical Assist Device Related Complication**	0 (0%)	0 (0%)	0 (0%)	----
Peripheral Vascular Complications				
Venous Thromboembolism-VTE**	5 (2.20%)	1 (4.55%)	4 (1.95%)	0.4022
Radial artery occlusion/ulnar neuropathy	2 (0.88%)	1 (4.55%)	1 (0.49%)	0.1848
Vasc-Iliac/Fem Dissect**	0 (0%)	0 (0%)	0 (0%)	----
Vasc-Acute Limb Ischemia**	0 (0%)	0 (0%)	0 (0%)	----
Hematology Complication				

Coagulopathy, anemia, HITT, +PF4	45 (19.82%)	9 (40.91%)	36 (17.56%)	0.0200*
Anticoag Event**	2 (0.88%)	0 (0%)	2 (0.98%)	1.00
GI Complication				
GI Event**	6 (2.64%)	1 (4.55%)	5 (2.44%)	0.4614
Dysphagia	7 (3.08%)	1 (4.55%)	6 (2.93%)	0.5151
Liver Dysfunction or Failure**	0 (0%)	0 (0%)	0 (0%)	----
Organ Failure				
Renal-Dialysis Req**	3 (1.32%)	2 (9.09%)	1 (0.49%)	0.0254*
Multi Sys Fail**	0 (0%)	0 (0%)	0 (0%)	----
Others				
– Safety concerns	13 (5.73%)	1 (4.55%)	12 (5.85%)	1.00
– Urinary retention	12 (5.29%)	0 (0%)	12 (5.85%)	0.6123
– Wound issues	8 (3.52%)	2 (9.09%)	6 (2.93%)	0.1756
– Medication Reaction	3 (1.32%)	0 (0%)	3 (1.46%)	1.00

*= P value <0.05 **data obtained from STS database

Post-Hospitalization Data (Refer to Tables 6 and 7)

A total of 22 patients (9.69%) were readmitted within 30 days of hospital discharge. The primary reason for readmission was CHF (n=6, 27.27%). The remaining readmission diagnoses included one patient each for a total of sixteen patients. It includes cardiovascular reasons (arrythmia or heart block, electrocardiography changes with shortness of breath, syncopal episode, and digoxin toxicity), pulmonary reasons (noncardiac chest pain, pleural effusion, pneumothorax, pneumonia, and respiratory failure related to pleural effusion), skin integrity issues (graft dysfunction, wound drainage issues), gastrointestinal issues (failure to thrive, cholecystitis, GI bleed), neuro-mental health issues (stroke/TIA) and musculoskeletal pain.

Table 6. *Reasons for Readmission within 30 days after discharge*

Readmission Reason	30-Day Readmission Group Frequency (%) (n=22)
Cardiovascular System	
CHF	6 (27.27%)
Arrhythmia or Heart Block	1 (4.55%)
Digoxin Poisoning	1 (4.55%)
SOB with chest pain and EKG changes	1 (4.55%)
Syncope	1 (4.55%)
Angina/ MI/CAD	0 (0%)
Aortic/Valve Complication	0 (0%)
Pericardial effusion and/or Tamponade	0 (0%)
Pulmonary System	
Chest pain-noncardiac	1 (4.55%)
Pleural effusion requiring intervention	1 (4.55%)
Hydropneumothorax	1 (4.55%)

PNA	1 (4.55%)
Pleural effusion, Respiratory failure, Syncopal episode	1 (4.55%)
DVT/PE/ Anticoagulation Dysfunction	0 (0%)
Infectious System/ Surgical Wound Integrity	
Infection, conduit harvest site	0 (0%)
Infection, Deep sternum/mediastinitis	0 (0%)
Endocarditis	0 (0%)
Pericarditis/post cardiotomy syndrome	0 (0%)
Sepsis	0 (0%)
Graft dysfunction	1 (4.55%)
Wound, other (drainage, cellulitis)	1 (4.55%)
GI System	
Failure to thrive	1(4.55%)
GI bleed	1(4.55%)
Electrolyte imbalance	0 (0%)
Cholecystitis	1 (4.55%)
Neuro –Psych Mental Health System	
Mental status change	0 (0%)
Psychiatric Issues	0 (0%)
Stroke/TIA	1 (4.55%)
Kidney System	
Renal Failure	0 (0%)
Renal Insufficiency	0 (0%)
Others	
Musculoskeletal Pain	1 (4.55%)

Most patients (70.48%) were discharged to home without home health support (n=99, 43.61%) or home with home health support (n=61, 26.87%). A total of 56 patients required a post-discharge stay in a skilled nursing facility (SNF)/rehabilitation (24.67%), inpatient rehabilitation unit (n=6, 2.64%), or other (long term nursing care facility) (n=5, 2.20%) (see Table 7). Discharge disposition was similar between groups (p= 0.234). Most patients were discharged to home (with or without home health support) in both groups although a larger percentage of patients in the non-RA group were discharged to home (72.20% vs. 54.54%). The percentage of patients who were discharged to home with home health support (27.27% in RA group vs. 26.83% in non-RA group) and discharged to short-term SNF/ rehabilitation facility (36.36% in RA group vs. 23.41% in non-RA group) were similar in among both groups.

Among all patients, only two patients (0.88%) required new outpatient HD at discharge. More RA patients required outpatient HD at discharge than did non-RA patients (n=2, 9.09%vs. n=0, 0%) (p= 0.009).

In the total sample, only 14.10% (n = 32) were seen for cardiothoracic physician follow-up within two weeks of hospital discharge, captured as ‘early clinic postoperative follow-up’. A total of five patients (22.73%) in the RA group were in early clinic follow-up and 27 patients (13.17%) in the non-RA group were seen in early clinic follow-up. While more of the RA patients were seen in earlier follow-up, no statistical significance was found between the two groups (p=0.209).

Table 7. *Post-Hospitalization Data Comparison Between RA Group and Non-RA Group*

	All patients	30-Day Readmissions Group (RA Group)	No 30-Day Readmissions (Non-RA Group)	P value
	Frequency (%) or Mean ± SD (n =227)	Frequency (%) or Mean ± SD (n = 22)	Frequency (%) or Mean ± SD (n = 205)	
Post Hospitalization Variables				
Need for Outpatient HD at discharge	2 (0.88%)	2 (9.09%)	0 (0%)	0.0090*
Discharge disposition				
– Home	99 (43.61%)	6 (27.27%)	93 (45.37%)	0.2341
– Home with Home Health	61 (26.87%)	6 (27.27%)	55 (26.83%)	
– SNF/Rehab	56 (24.67%)	8 (36.36%)	48 (23.41%)	
– Inpatient Rehab	6 (2.64%)	1 (4.55%)	5 (2.44%)	
– Other	5 (2.20%)	1 (4.55%)	4 (1.95%)	
– Expired	0 (0%)	0 (0%)	0 (0%)	
Early clinic postoperative follow-up	32 (14.10%)	5 (22.73%)	27 (13.17%)	0.2092

*= P value <0.05

Predictive Scoring Systems and 30-Day Readmissions

The mean LACE+ score for all patients was 53.59 ± 21.40 indicating moderate risk for early death or readmission within 30 days. There was no statistically significant difference in the mean LACE+ score (p= 0.202) between the study groups.

The mean STS predicted risk of mortality was 1.7% ± 1.9 (low risk) with a mean predicted morbidity and mortality score of 10.7% ± 7.7. When assessing the STS predicted risk of mortality, there was no observed statistical significance between the groups (3% in RA group versus 1.5% in non-RA group, p= 0.065); however, the STS predicted risk of morbidity and mortality score was higher in the RA group (16.63% vs. 9.96% in the non-RA group; p=0.025).

Table 8. *LACE Plus Score and STS Predicted Mortality Scores Comparison Between RA Group and Non-RA Group*

	All patients	30-Day Readmissions	No 30-Day Readmissions	P value
	Frequency (%) or Mean ± SD (n = 227)	Frequency (%) or Mean ± SD (n = 22)	Frequency (%) or Mean ± SD (n = 205)	
Comorbidity Variables				
Mean LACE+ score	53.59 ± 21.40	59.14 ± 20.28	53.00 ± 21.48	0.2018
STS predicted risk of mortality score	1.7% ± 1.9	3.0% ± 3.39	1.53% ± 1.61	0.0650
STS predicted risk of morbidity and mortality score	10.7% ± 7.7	16.63% ± 12.50	9.96% ± 6.66	0.0254*

*= P value <0.05

Predictive Factors for 30-Day Readmissions in Cardiac Surgery Patients (Refer to Table 9).

Additional analysis was performed to determine the predictive factors of readmission within 30 days of hospital discharge. Logistic regressions were performed utilizing backward elimination and forward selection to find the best fit model. Length of CPB time showed a weak positive correlation with 30-day readmissions after discharge post-cardiac surgery as did female gender. However, both CPB time and female gender were statistically significant predictive factors for 30-day readmissions (p= 0.01 and p= 0.02, respectively) in this population. The backward elimination model had a max rescaled R-square value of 0.1372, indicating a weak predictive model. This adjusted R-square is a number between 0 and 1, and the higher the number, the better the model is at predicting the outcome of interest, in this case predicting 30-day readmissions after cardiac surgery (Refer to Table 9).

In the forward selection model, only the STS predicted risk of morbidity and mortality score was significant in predicting 30-day readmissions after hospital discharge (p= 0.001) in this population. The predicted morbidity and mortality score had a strong, positive correlation with increased risk for readmission. This model had a max rescaled R-squared value of 0.1061, which also indicated a weak predictive model for predicting 30-day readmissions after cardiac surgery.

In conclusion length of CPB time, female gender, and the STS predicted risk of morbidity and mortality score were found to be predictive of 30-day readmission in patients who underwent cardiac surgery, using alpha of 0.05. Using an alpha of 0.10, highest postoperative serum creatinine level showed to be predictive of 30-day readmission with a weak correlation of 0.4205.

By gender, males were more dependent on length of CPB time to predict 30-day readmissions than females with an alpha of 0.10; whereas, the STS predicted risk of morbidity and mortality score as well as having hematological postoperative complications (coagulopathy, HITT, anemia or + PF4) were two significant predictors to predict 30-day readmissions in females at an alpha of 0.10.

Table 9 *Predictive Variables for 30-Day Readmissions Using Logistic Regression*

Readmission within 30-days of discharge	Estimate (Correlation Direction)	P value
Length of CPB time*	0.0144	0.0052***
Gender-female*	0.551	0.0232***
STS predicted risk of morbidity and mortality score**	7.8506	0.0009***
Highest postoperative serum creatine level *	0.4205	0.0567

*utilized backward elimination method, **utilized forward selection method, *** = p <0.05

Chapter 5: Discussion

Early readmissions can be detrimental to healthcare facilities' finances due to future monetary penalties through decreased reimbursement payments for specific surgical procedures (Bergethon et al., 2016; Kripalani et al., 2014; CMS, n.d.). Decreasing readmission risk is a multifactorial process that can be accomplished through identification of high risk patients and timely monitoring after discharge. This requires identification of risk factors and utilizing an effective and accurate risk stratification scoring system. This study reevaluated whether previously identified risk factors are predictive of 30-day readmissions after cardiac surgery in this study's setting. This study also compared several risk stratification scoring systems to determine their effectiveness at predicting 30-day readmissions in adult cardiac surgery patients.

Identification of Risk Factors of 30-day Readmissions After Cardiac Surgery

Demographic and Comorbidity Variables. Previous studies reported that the most prevalent demographic and comorbidity risk factors of age greater 65 years of age, females, African-Americans, comorbidities of CHF, DM, COPD, increased BMI, or renal failure place patients at higher risk for readmission after cardiac surgery (Espinoza et al., 2016; Fasken et al., 2001; Hannan et al., 2011; Lella et al., 2015; Li et al., 2012; Maniar et al., 2014; Redžek et al., 2015; Shehata et al., 2013; Shirzad et al., 2010; Slamowicz et al., 2008). Differently, our study observed that only female gender and a history of CHF increased risk for 30-day readmissions after cardiac surgery but failed to observe that age, race, DM or higher BMI impacted 30-day readmission rates.

This study found that the female patients are 2.3 times more likely to be readmitted within 30 days after discharge than the male patients (15.4% in female vs 6.7% in male, p= 0.0359). In the correlation analysis, female gender time was a moderate, positive predictor of readmissions (correlation r= 0.55, p=0.02). These results were consistent with the findings of previous studies (Hannan et al. 2011; Iribarne et al., 2014; Li et al., 2012; Shehata et al., 2013; Slamowicz et al., 2008). Nicolini et al. (2016) stated that women are at higher risk for readmission due to smaller body habitus contributing to smaller coronary vasculature therefore complicating complete revascularization and resulting in increased risk of myocardial infarction as well as readmissions related to heart failure. In a prospective ten-year study, Nicolini et al.

(2016) found that women experienced higher rates of myocardial infarction (MI) as well as stoke compared to males in the follow-up period post cardiac surgery.

Previous studies reported that patients over 65 years, non-Caucasian ethnicity, or low-income were more likely to have early readmission after cardiac surgery (Hanna et al., 2011; Li et al., 2012; Shirzad et al., 2010; Slamosicz et al., 2008). Differently, neither age nor race were found to be a significant predictor of readmission in this study's population. The inconsistency of this finding could be contributed to inequality of race distribution in the sample where a majority of the population (92.92%) was Caucasian.

Lee et al. (2012) reported that a history CHF was associated with 30-day readmissions after cardiac surgery and was a top cause for readmission. Similar findings were found in the current study. CHF was the most prevalent cause of 30-day readmissions in post-cardiac surgery (27.3%). A history of CHF showed a significant relationship with readmissions, with 45.5% of readmitted patients having a history of CHF ($p = 0.01$); however, it was not a significant predictive variable ($p = 0.58$) in the logistic regression model. Unfortunately, this study did not include COPD as a comorbidity, which limits comparison with previous studies.

Surgical Variables. Previous researchers reported that complicated surgeries such as combination CABG/valve or dual valve surgery or LVAD/transplant surgery increase patients' risk for readmission within 30 days of discharge as well as a longer CPB time and length of surgery contributed to 30 day readmission risk (Espinoza et al., 2016; Iribarne et al., 2014; Lee et al., 2012; Pack et al., 2016). In Espinoza et al.'s study (2016), CPB time greater than 100 minutes was a significant variable for readmission. The current study's findings are consistent with previous studies. RA patients had longer CPB time (122.1 minutes ± 59) than non-RA patients (100.7 minutes ± 46) ($p < 0.05$). In the correlation analysis, CPB time was a weak, but significant predictor (correlation r= 0.02, *p*=0.01) of readmission within 30 days of discharge after cardiac surgery. Longer CPB time and longer total surgery time can indicate the complexity of the surgical procedure. However, in this current study neither the complexity of procedures (aortic procedures, CABG/valve procedures, and combination valve procedures) nor having previous sternotomy showed to influence 30-day readmissions. Small sample size of patients undergoing complex surgery may contribute to this insignificant finding.

In-Hospitalization Overall Clinical Variables. Previous studies reported that low hematocrit, low ejection fraction, increased serum creatinine level greater than 2.00, hyperglycemia greater than 200 mg/dL, having post-surgical complications such as arrhythmias (especially AF), infection, longer overall and ICU length of stay were strong predictors for 30-day readmissions in post cardiac surgery patients (Espinoza et al., 2016; Fasken et al., 2001; Hannan et al., 2011; Iribarne et al., 2014; Li et al., 2012; Maniar et al., 2014; Pack et al., 2016; Redžek et al., 2015; Shehata et al., 2013; Shirzad et al., 2010; Slamowicz et al., 2008).

Low Hematocrit and Hematology Complication. The current study observed that lower HCT during hospitalization impacts 30-day readmissions after cardiac surgery. RA patients had a lower HCT (23.99 ± 4.46) compared to non-RA patients (26.45 ± 5.11) (*p*=0.03). Espinoza et al.'s (2016) study showed that a hematocrit less than 35% before surgery increased patients' risk for readmission while Iribarne et al.(2014) found that higher hemoglobin levels were protective against readmissions after cardiac surgery.

This study also observed a higher proportion of patients in the RA group experienced the hematologic complication of coagulopathy, anemia, HITT, +PF4 than in the non-RA group (n=9, 40.91% in the RA group compared to n=36, 17.56% in the non-RA group; *p*= 0.02). Undergoing CPB as well as a sternotomy increases the risk of adverse coagulation event due to the multiple hemostatic mechanisms related to tissue injury and mechanical injury resulting from the CPB pump (Levy, 2013). The main pharmacologic anticoagulant used during CPB is heparin and the longer the CPB time, the longer exposure to heparin which may increase the chance of reaction or development of PF4 antibodies (Ahmed, Majeed, & Powell, 2007; Levy, 2013). Both HITT and PF4 antibodies cause platelet counts to decrease (Ahmed et al., 2007), thus disrupting the clotting cascade in the postoperative period. If coagulopathy occurs, patients may require blood transfusion to help correct anemia. While blood transfusions were not a significant influence on readmissions in the present study, other researchers supported the notion that an increase in blood product transfusion leads to increase in readmissions after cardiac surgery (Li et al., 2012; Pack et al., 2016). For future practice, early identification of these patients through point of care coagulation testing in the postoperative period may help to deter adverse outcomes and decrease risk of readmission in this population (Karkouti et al., 2015). Low hematocrit levels in the perioperative timeframe may contribute to prolonged inotropic use, prolonged oxygen therapy or patients classified as having anemia or coagulopathy, although it is difficult to confidently report this as these variables were not correlated together during the data analysis. It is well documented that bleeding/coagulopathy complications can have adverse outcomes in cardiac surgery patients such as increase length of stays, increase 30-day readmissions, and cost increase accrued by the patients (Stokes et al., 2011; Wan et al., 2017).

Renal Function. This study showed that significant decline in renal function requiring higher level of care such as HD or CRRT (p=0.03) strongly influenced 30-day readmissions. Similarly, higher postop creatinine levels were seen in the in the RA group than in non-RA group (1.68 in RA group vs. 1.15 in non-RA group), although this was not a statistically significant finding (p=0.0811). Logistical regression showed a weak, positive correlation of 0.42 between serum creatinine and readmissions using an alpha of 0.10 (p=0.06). The current study's findings were similar to those found by Espinoza et al. (2016) and increasing the threshold of only capturing serum creatinine greater than 2.00 may yield more significant results as it did in Espinoza et al.'s (2016) study. Hannan et al. (2011) cited significant, positive logistic regression correlations in patients who required dialysis in the preoperative period or encountered renal failure as a postoperative complication (p= 0.01 and p=0.002, respectively) and were readmitted postoperatively.

In regard to CRRT, two patients that required only CRRT postoperatively were not readmitted; however, of the three patients that required both CRRT and HD, two were readmitted within 30-days and this was statistically significant (p=0.034). This may indicate that usage of CRRT for AKI can provide protective effects against readmissions. The current study's sample is too small to make this generalized statement; however, literature does support that renal replacement can help achieve fluid balance in cardiac surgery patients more quickly than pharmacological agents and can help deter the adverse effects of prolonged volume overload (Gibney et al., 2008; Nadim et al., 2018). Researchers also theorize that early initiation of renal replacement therapy before onset of AKI may improve survival and promote early kidney recovery, thereby decreasing adverse effects from kidney injury (Gibney et al., 2008; Nadim et al., 2018). This knowledge may be applicable in our study's population and help to further decrease 30-day readmissions.

Ejection Fraction. Different from previous studies, the current study did not find significant correlation in ejection fraction during hospitalization. The current researchers found that history of CHF independently influenced 30-day readmissions although LVEF measured during hospitalization was not predictive of it. With the majority of the study's patients having normal LVEFs in both groups, this may indicate that heart function was well controlled even in CHF patients during hospitalization and it was awarded back with no differences in 30-day readmission. In another aspect, the current study only collected data on presence of CHF and did not differentiate whether the heart failure was systolic or diastolic. In a study conducted by Dalén, Lund, Ivert, Holzmann, & Sartipy (2016), patients with HF were at risk for an increase in all-cause mortality after CABG procedure independent of LVEF. However, further investigation is warranted to identify presence of diastolic or systolic heart failure as this discrimination may serve as better predictors of cardiac surgery postoperative outcomes (Dalén et al., 2016) with regards to heart failure patients.

Length of stay. Readmitted patients had a clinically longer initial postoperative stay in the ICU (124.0 hours ± 148) compared to non-RA patients' ICU LOS (73.33 hours ± 83.24). This was not statistically significant (p=0.13). This finding may hold clinical significance as RA patients had a 50 hour longer LOS in the ICU. The overall mean HLOS for RA patient was 11.18 days ± 14 and 7.32 days ± 6 for non-RA patients. While this finding does not show statistical significance (p= 0.21) but may be clinically significant as RA patients had a longer HLOS by almost four days.

It is well documented that longer HLOS and ICU LOS increase risk for readmission after discharge (Fasken et al., 2001; Hannan et al., 2011; Maniar et al., 2014; Pack et al., 2016; Shehata et al., 2013; Slamowicz et al., 2008; Sun et al., 2008). Shehata et al. (2013) and Hannan et al. (2011) reported similar findings in their studies with patients readmitted after cardiac surgery having a longer HLOS by four days. In their systematic review, Fasken et al. (2001) stated that patients discharged earlier had a decreased risk of developing adverse outcomes associated with cardiac surgery. Patients with longer HLOS may have encountered difficulties during recovery and are more likely to be readmitted due to complications from surgery (Fasken et al., 2001).

Post-hospitalization Variables.

The readmission rate in this study was 9.7%, which was lower than the CMS (n.d.) reported national rate (13.8%) but higher than Virginia's readmission rate (7.2%) (VHI, 2018a). The primary reason for readmission in the present study was found to be CHF (n=6, 27.27%), which is consistent of the findings from the previous studies (Hannan et al., 2011; Li et al., 2012; Pack et al., 2016; Redžek et al., 2015; Sun et al., 2008). The remaining readmitted patients (n=16) returned to the hospital within 30-days of discharge for a variety of reasons (see Table 6), but no diagnosis category included more than one patient.

In the previous studies, infections and dysrhythmias (after CHF) have been mentioned as primary reasons for 30-day readmissions after cardiac surgery (Hannan et al., 2011; Li et al., 2012; Pack et al., 2016; Redžek et al., 2015; Sun et al., 2008). In the current study, one patient (4.55%) was readmitted with an arrhythmia complication and no patients were readmitted due to infection.

Among all 227 patients, only two patients (0.88%) required new outpatient HD at discharge. However, those two patients (n=2, 9.09%) were readmitted within 30-days of hospital discharge making this a significant finding (p= 0.009). In line with previous discussions, risk of 30-day readmissions was shown to be statistically significant (p=0.03) in patients that required both CRRT as well as hemodialysis during their hospitalization. It is known that patients who require dialysis preoperatively are at higher risk for readmission after cardiac surgery (Hannan et al., 2011). It is no surprise that patients requiring new hemodialysis at discharge are at higher readmission risk as these patient populations have been shown to have higher mortality rates, longer ICU LOS as well as HLOS (Crawford et al., 2017; Malov et al., 2014).

A large portion of this study's population was discharged to home (n=160, 70.5%). Of those patients, most did not receive home health services (n=99, 43.61%), although 61 patients (26.87%) did receive these services. About one fourth (n=56, 24.67%) of patients were discharged to SNF/rehab centers. Discharge disposition was not a significant predictor of 30-day readmission in this study. In this study, over half of patients (n=117, 51.54%) were discharge to a post-acute care (PAC) facility or had the resource of home health after discharge. Stoicea et al. (2017) advocate for PAC facilities such as SNFs and long-term acute care facilities as well as utilizing home health to help improve recovery and decrease risk of hospital readmissions after cardiac surgery. Encouraging patients who prefer to be discharged home to utilize home health may help to further decrease readmission rates in our population.

Predictive Scoring Systems and 30-day Readmissions

In this study, the mean LACE+ score for all patients was 53.59 ± 21.40 indicating moderate risk for early death or readmission within 30 days. The mean LACE+ score for readmitted patients was 59.14 ± 20.28 categorizing this group as high risk for readmission; whereas, the mean LACE+ score for non-readmitted patients was 53.00 ± 20.28. However, no statistical significance was found between the study groups (p=0.020).

The LACE+ score had been used in a variety of surgical populations to predict the 30-day readmission rates after discharge (Garrison et al., 2017; van Walraven et al., 2012). However, its applicability and validity in cardiac surgery patients has not been supported by the current researcher. This could be due to the small sample size of readmitted patients (n=22). Further study with a larger sample size needs to be done to determine the predictability of LACE + score in post cardiac surgery patients.

The mean STS predicted risk of mortality was 1.7% ± 1.9 (low risk) for all patients with a mean predicted morbidity and mortality score of 10.7% ± 7.7. The STS predicted risk of mortality was higher in the RA group (3%) than in non-RA group (1.5%); however, no statistical significance was found. Different from the two other risk stratification systems, this study observed that the STS predicted risk of morbidity and mortality score was sensitive to predict 30-day readmission rates. The STS predicted risk of morbidity and mortality rate was significantly higher in RA group (16.63%) than in non-RA group (9.96%) with a p value of 0.025. In the forward-selection logistical regression model, the STS predicted risk of morbidity and mortality score yielded a very strong, positive correlation with 30-day readmissions ($r=7.8506$, $p=0.0009$).

Different from the LACE+ score, which addresses approximately fourteen variables (van Walraven et al., 2012), the STS risk calculator addresses approximately 100 variables categorized into demographics, hospitalization, risk factors (weight, lab values, etc.), previous interventions, preoperative cardiac status, preoperative medications, hemodynamics and catheterization, operative, and mechanical assist devices (STS, 2018c). This calculator also gives a percentage chance of specific outcomes such as renal failure, stroke, infections, etc. in addition to the predicted risk of mortality score and the predicted morbidity and mortality score (STS, 2018c). Consideration of addressing the multiple but sensitive clinical predictors into the scoring system may attribute to the superiority in predicting the 30-day readmission rate.

However, it is important to note that all scoring systems are only accurate if all risk variables are answered in the EMR (Shahian et al., 2018; STS, 2018c). The STS predicted risk of mortality score as well as the predicted risk of morbidity and mortality score are calculated after information is entered an online calculator (STS, 2018c). This is similar for the LACE+ score as well. Currently, the STS risk scores are not routinely documented in the EMR during patients' hospitalization and are usually only available after formal data abstraction long after the patient has been discharged. Without consistent compliance to document all the variables available at the time of discharge, the calculation of STS scores and LACE+ score would be questionable. Considering the feasibility associated with the number of variables to be entered and available, LACE+ score would be more feasible. To use the STS score with accuracy, the compliance of documentation would be critical.

While the STS scores are useful to cardiothoracic surgeons preoperatively to gauge operative mortality risk or possibility of operative complications as well as aid decision making for treatment modality, limitations exist. Some of the STS variables include postoperative data, (such as the need for mechanical assist devices) (Shahian et al., 2018; STS, 2018c) and must be addressed to give the best risk score. If the scores are calculated preoperatively, this score may increase or decrease depending on the postoperative course. Ideally, in order to best identify patients at risk for readmission after surgery, the STS risk scores will need to be calculated, documented, and retrievable in the EMR prior to the patient discharging from the hospital. Currently, the STS risk scores are not routinely documented by providers in the EMR. If the STS risk scores are not documented into the EMR, discharging providers do not have immediate access to those scores, complicating use of this risk score to identify patients at high risk for readmission. Utilizing an automated computerized decision-making system (aCDMS) that integrates the STS risk scores as part of the patients' EMR could encourage use of the STS scores at time of discharge.

Strength and Limitations of the Study

This study has both strengths and limitations. One strength of this study is that it is the first study to be completed at the study's site in the cardiac surgery population identifying predictors of readmissions within 30-days of cardiac surgery. In doing this study, discharging providers have knowledge, based in research, as to which patient characteristics predispose them to the likelihood of readmission. This will allow discharging providers to identify more concisely those patients and plan discharge interventions focused on decreasing readmissions.

Another strength of this study is that researchers included all cardiac surgery patients with the exception of minimally invasive procedures. A majority of current research is primarily focused on CABG patients due to the Medicare procedure reimbursements in place. By including at all non-minimally invasive surgeries, researchers are able to generalize findings to that population in in the study's setting and thus able to make appropriate future recommendations.

In addition to its strengths, this study has the limitation of sample size. The study contained only 227 patients undergoing surgery in a six-month timeframe and was completed at a single center. Previous research studies assessing predictors of readmission were completed with thousands of participants and at multiple centers. While the researchers are able to draw some conclusions from this study, a larger sample may have yielded different results. Increasing the data collection period would yield a larger sample.

It is important to note prior to this study, readmission rates after cardiac surgery had significantly decreased at this facility over the previous five years. Interventions have been in place to identify high risk patients, and discharge actions have been implemented. With these ongoing interventions, consistently identifying high risk patients and tailoring interventions accordingly will be key for further decreased readmission rates.

Implications for Nursing Practice

This study is a repeated study in that it identifies predictors of readmissions within 30-days of cardiac surgery including all demographic and comorbid disease data, in-hospital clinical data including complications and post-discharge data. A majority of current research is primarily focused on only CABG patients for which the Medicare procedure reimbursements are already in place. By including at all non-minimally invasive cardiac surgeries, researchers are able to generalize findings to all cardiac surgery populations and thus able to make appropriate future recommendations.

This study yields multiple implications for advance nursing practice. Researchers of this study were able to identify that female gender, history of CHF, having longer CPB time, low hematocrit, necessity of postoperative HD alone or with CRRT, coagulopathies including anemia, HITT, and positive PF4 were associated with 30-day readmission rates after cardiac surgery. The LACE+ score has been used in the current setting to predict 30-day readmission, but this study showed it was not effective to predict 30-day readmission in patients who underwent cardiac surgery. Rather, the STS predicted risk of morbidity and mortality was predictive of 30-day readmissions in this study.

At the current study site, patients are to follow-up with their primary care provider within 2 weeks or discharge and with the surgeon within 30 days of discharge. Early identification of high risk patients having the above-mentioned risk factors and or utilizing a risk stratification system will help to guide proper discharge planning as well as interventions geared towards deterring readmissions. It may be beneficial to identify patients with the above-mentioned risk factors in the EMR and provide an alert to discharging providers that an early hospital follow-up phone call within 24 hours of discharge is warranted. This would allow communication and identification of health issues that may potentially bring the patient back to the hospital, as recommended by Quader et al. (2017). Also, scheduling patients with identified risk factors for earlier clinic follow-up, likely within one to two weeks of discharge can be arranged to decrease readmission rates in this population.

Researchers found in this study that CHF was the predominant diagnosis for patients readmitted within 30 days of cardiac surgery. While much work has been done to decrease these readmissions and emphasis has been placed on heart failure education, this is still the study center's number one readmitting diagnosis in patient who recently underwent cardiac surgery. Collaborating with the heart failure management team may alleviate time constraints by the cardiothoracic discharging team and provide patients with focused HF discharge instructions including daily weight monitoring, control with diuretic, providing a take-home weight scale and additional resources after discharge. This intervention may help decrease future CHF readmissions in the study population.

Implications for Future Research

As a retrospective, case control study, this study identified predictors of 30-day readmissions in cardiac surgery patients as well as assessing the accuracy of a risk stratification scoring system, the LACE+ score. In this study the LACE+ score was not predictive in identifying patients at risk for readmission. However, the STS predicted risk of morbidity and mortality score was a strong predictor of hospital readmission. While this was shown as effective to predict 30-day readmissions, it requires entering data for up to 100 variables, which make this a bulky process for discharging providers. A future study comparing and correlating the previously identified scoring systems, Espinoza et al.'s (2016) and Pack et al.'s (2016) scoring systems with 30-day readmissions may allude to a quicker risk stratification system that is easily utilized in the discharging process of cardiac surgery patients. In a future study, the significant variables in this study can be given a numerical weight, allowing a score to be calculated and correlated with 30-day readmissions in the study's cardiac surgery population. This score could then be compared with Espinoza et al.'s and Pack et al.'s scores to determine which one is the most accurate in the study setting's cardiac surgery population.

The study also contained small sample size of 227 patients undergoing cardiac surgery in a six-month timeframe with only 22 patients who were readmitted within 30 days. While the researchers from this study were able to draw some conclusions, a further study is warranted with a larger sample size.

This study also identified CHF as being the predominant diagnosis for readmission in our study population. A history of CHF was also found to influence readmissions after cardiac surgery. Based on the researchers' findings concerning ejection fraction percent, most patients had a normal EF. Therefore, further investigation into the type of heart failure the study setting's patients most commonly have can help to further guide discharge interventions specific to either systolic heart failure or diastolic heart failure management.

Conclusion

Previous research studies identified numerous variables that increase patients' risk for readmission after cardiac surgery. Research has also shown that early identification of these variables can help modify interventions directed at decreasing readmission rates. This study identified that female gender, history of congestive heart failure, longer CPB time, low hematocrit, coagulopathy, anemia, HITT, positive PF4, necessity of postoperative hemodialysis together or alone with CRRT and need for outpatient hemodialysis at discharge were associated with 30-day readmissions after cardiac surgery. The STS predicted risk of morbidity and mortality risk score was identified as a strong predictor of 30-day readmissions in this population as well, different from the LACE+ scoring system. Identification of high-risk patients using the STS predicted risk of morbidity and mortality score with appropriate interventions including discharge education, close monitoring, and early follow-ups will help reduce 30-day readmissions in patients who undergo cardiac surgery. Utilizing an automated computerized decision-making system (aCDMS) that integrates the STS risk scores as part of the patients' EMR could encourage use of the STS scores at time of discharge. Also, collaboration with the heart failure team can also help optimize management of heart failure and reduce 30-day readmission rates.

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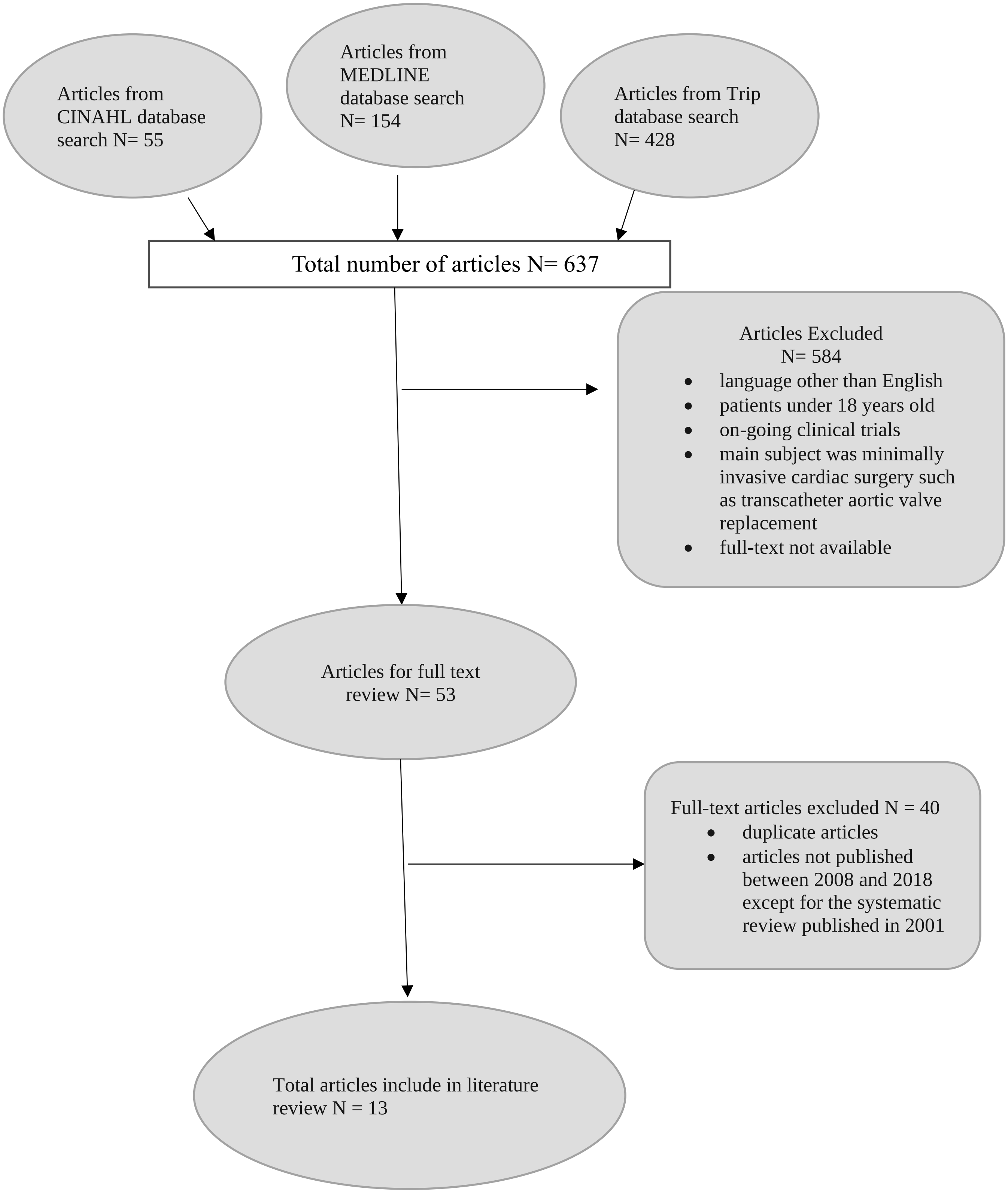
Appendix A

Decision Tree Summary of Literature Review Results



Appendix B
Evaluation and Synthesis of Evidence

Author (Year) & Level of Evidence	**Design/ Method**	**Sample/ Setting**	**Major Variables Studied (and their definitions)**	**Measurement**	**Data Analysis**	**Findings**	**Comments**

Espinoza et al. (2016)
 	
Level IV
	Retrospective analysis
	
	Purpose: to develop and implement a clinical score to predict 30-day readmissions after cardiac surgery by accounting for all known-major risk factors
		N= 5,148 patients (2,529 used to develop tool and 2,567 used to validate tool)
		
		Setting: Buenos Aires Cardiovascular Institute (acute care)
		
		All cardiac surgery
			IV: Risk factors;
			Preoperative:
			• Age
			• Gender
			• DM
			• Recent hx for MI
			• Hct
			Intraoperative:
			• Sx type:
			  ○ AV
			  ○ MV
			  ○ CABG only
			• Combined surgery
			• Thoracic aortic replacement
			• CABG as an associated procedure
			• Conduits used for CABG
			• CPB
			  ○ < 100 minutes
			  ○ ≥ 100 minutes
			• Ascending aortic calcification
			• OR extubation
			Postoperative:
			• HLOS
			• Inotropic medication
			• Afib
				Patient characteristics
				
				Risk factors in association with 30-day readmission
				
				Overall 30-day readmission
					Chi-square or Fisher's exact to develop scoring system
					
					Stepwise logistic regression model used to choose early predictors
					
					Frequency & percentages
					
					OR
					
					95% CI
						30-day readmission = 11.7% of entire sample
						
						Risk factors associated with readmission: older age, female, hct ≤ 35%, DM, CPB and prolong CBP, ascending aortic calcification, valve surgeries, longer HLOS, inotropic medication, Afib, ARF, hyperglycemia, OR extubation
						
						6 most predictive variables:
						• DM (p value =.004, OR 1.57, CI 1.15-2.13)
						• preoperative hct (≤ 35%) (p value =.019, OR 1.45, CI 1.06-1.97)
						• CPB < 100 mins (p value =.007, OR 1.62, CI 1.14-2.30), or CPB > 100 mins (p value = .000, OR 2.70, CI 1.95-3.72)
						• highest glycemic level (p value =.024, OR 1.39, CI 1.04-1.84)
						• Afib (p value =.039, OR 1.37, CI 1.02-1.84)
							Scoring system as a clinical practice guideline to implement in cardiac surgery patients to predict readmissions
							
							Points given for each risk variable (i.e. longer CPB time is worth 2 points, all others are worth 1 point)
							
							Higher score = greater risk for readmission

			• ARF
			• Peak serum creatinine level during hospital stay
			  ○ ≥ 2.00 mg/dL
			• Peak serum glycemic level
			  ○ ≥ 200 mg/dL
			
			DV: 30-day readmissions				

Fasken et al. (2001) **Level I**	SR Purpose: Determine predictors of unplanned readmissions in cardiac surgery patients Searched 2 databases for literature from 1989-1999	N= 17 articles Elderly, Caucasian males Retrospective analysis of large data sets from mostly VA hospitals CABG only	IV: Cardiac surgery/procedures, factors associated with readmissions, race, gender, LOS, quality of care, psychosocial factors, complications after surgery, comorbid conditions DV: Unplanned readmissions	Days to readmission: 7 day- 365 days Patient characteristics	Frequency/percentages of readmissions per study	Readmissions ranged from 3.2-30.6% CABG patients at highest risk include: AA, females, longer LOS, low SE status, comorbid conditions such as CHF and COPD	Majority of sample was elderly, Caucasian males, therefore hard to generalize findings to other populations
Hannan et al. (2011) **Level IV**	Retrospective analysis Purpose: identify reasons for and predictors of readmission	N = 30,953 patients New York state hospitals between 2005-2007 CABG only	IV1: Reasons for readmission IV2: Predictors of readmission DV: 30-readmission rate	Demographic data Pre-/post-operative factors • Risk factors for all cause readmission within 30-day • Risk factors for readmission due to infection within 30-day	Stepwise logistic regression Frequency OR 95% CI	All cause readmission rate 16.5% (range 8.3%-21.1%) Mortality rate: 0.76% Diagnosis for readmission: • Infection 16.9% • HF 12.8% • Other 9.8% • Dysrhythmia 6.3% • Chest pain 4.7% Risk factors for readmission: • Females (OR= 1.23, CI = 1.16-1.29, p Value =<0.0001)	Also investigated patients at risk for readmission due to infections: women, obese, unplanned reoperations, and longer LOS were significant for this finding Only 30-day readmissions

				Principle diagnosis for readmission within 30 days
				
				Mortality
				
				Hospital CABG volume
				
				Surgeon CABG volume
				
				Insurance type
						• Age > 70 (OR= 1.02, CI = 1.01-1.03, p Value =<0.0001)
						• African American (OR= 1.16, CI = 1.01-1.32, p Value =0.03)
						• BMI
						  ○ 30.1-34.9 (OR= 1.14, CI = 1.04-1.24, p Value =0.004)
						  ○ 35-40 (OR= 1.29, CI = 1.17-1.43, p Value <0.0001)
						  ○ > 40 (OR= 1.62, CI = 1.42-1.84, p Value <0.0001)
						• Comorbid disease-CVA, PVD, CHF, aortic atherosclerosis, COPD, DM, 3VD, immune system deficiency, previous PCI, organ transplant, EF < 30%, RF (ranges of OR= 1.06-1.79, p Value ranges <0.001-.03)
						• Dialysis (OR= 1.46, CI = 1.11-1.91, p Value =0.007)
						• Unplanned reoperation (OR= 1.62, CI = 1.24-2.12, p Value =0.0005)
						• D/C disposition other than home
						  ○ SNF (OR= 1.45, CI = 1.30-1.62, p Value <0.0001)
						  ○ IP rehabilitation (OR= 0.57, CI = 0.39-1.36, p Value =0.005)
						• LOS (Ranges: OR= 1.31-2.07, CI = 1.19-2.43, p Value =< 0.0001
						• Only saphenous vein graft (OR= 1.18, CI = 1.03-1.36, p Value =0.02)
							were included in study
							
							Recommended patients with numerous risk factors for readmission be closely monitored

Iribarne et al. (2014)
 	
Level III
	Prospective observational cohort study
	
	Purpose: examine the frequency, timing, and associated risk factors for readmission after cardiac operations
		N= 5, 059 patients
		
		10 centers in the US and Canada over 7 months
			IV: Patient and operative characteristics
			
			DV: All cause hospital readmission within 65 days
				Patient and operative characteristics
				
				Timing of first readmission
				
				Readmission rate
				
				Causes of readmissions
					Frequency
					
					HR
					
					95% CI
					
					Multivariable Cox regression
						Rate of readmission = 18.7%
						
						Readmission rate by Procedure type:
						• CABG: 14.9%
						• Valve only: 18.3 %
						• CABG + valve: 25%
						• LVAD/Tx: 35.1%
						• Thoracic Aortic: 18.1%
						• Other: 21.5%
						
						Risk Factors associated with Readmission:
						• Female (HR 1.35, CI 1.16-1.57, p value < 0.001)
						• DM (HR 1.35, CI 1.15-1.59, p value < 0.001)
						• COPD (HR 1.42, CI 1.19-1.68, p value < 0.001)
						• Elevated creatinine (HR 1.10, CI 1.05-1.15, p value < 0.001)
						• Higher Hgb (HR 0.91, CI 0.88-0.95, p value < 0.001)
						• Duration of Sx (HR 1.15, CI 1.10-1.20, p value < 0.001)
						• Type of Sx:
						  ○ Valve (HR 1.33, CI 1.11-1.60, p value = 0.002)
						  ○ CABG/valve (HR 1.52, CI 1.23-1.88, p value < 0.001)
						  ○ LVAD/tx (HR 3.36, CI 2.34 -
							Mena age of patients ~ 64.3 and consisted of mostly white men
							
							Infection and arrhythmias most common causes of readmission within 30 days and infection and volume overload most common readmission > 30 days
							
							Only conducted at academic centers
							
							Suggests that further studies determine which readmission strategies are most effective in this population

						4.84, p value < 0.001) ○ Thoracic aortic (HR 1.40, CI 1.06-1.85, p value = 0.017) ○ Other (HR 1.41, CI 1.06-1.89, p value = 0.019)	
Lella et al. (2015) **Level IV**	Retrospective analysis Purpose: significance of abnormal RVEF in predicting outcomes of patients undergoing isolated CABG and valve surgery	N= 109 patients CABG and valve procedures Acute care hospital	IV: abnormal RVEF and LVEF defined by EF < 35% and < 45% respectively DV1: Short term outcome (< 30 days) including perioperative complications, LOS, cardiac-rehospitalizations, and early mortality DV2: long term outcomes (> 30 days) including cardiac re-hospitalization, worsening CHF, and mortality	30-day outcomes Perioperative complications ICU readmissions Repeat cardiac hospitalizations within 30 days Mortality Long term outcomes Candidate variables	Frequency t-test Fisher's exact test Multivariable logistic regression 95% CI HR	Mean age 66 ± 12 years 38% women No 30-day repeat cardiac hospitalizations observed >30-day outcomes showed higher repeat cardiac hospitalization in abnormal RVEF (31% versus 13%, p = .032) Long-term rehospitalization (cardiac cause) RVEF <35%: 3.011 HR, 1.151-7.879 CI, p value = 0.025; LVEF was not a significant predictor	Only single institute study with limited sample size Cardiac MRI was utilized to determine EF preoperatively Suggest using CMR as a pre-operative risk stratification tool
Li et al. (2012) **Level IV**	Retrospective analysis Purpose: to identify sources of variation associated with readmission rate after CABG procedures	N= 11,823 patients; 119 hospitals Patient discharged from California hospitals from 2009-2010 CABG only	IV1: Patient level including demographic and perioperative clinical risk factors, postoperative complications, health insurance, SE status IV2: hospital characteristics including teaching status, type of ownership, licensed bed size, CABG surgery volume, and geographic location	Principle diagnosis Readmission rate Patient risk factors Variable for 30-day readmission	Frequency Standard and hierarchical multivariable logistic regression OR 95% CI	13.2% patient readmitted in 30-days Readmission reasons: HF and infection were most frequent 15.3% and 12.9% respectively Risk Factors for 30-day readmission: • Age ○ 75-84 (OR: 1.365, CI: 1.135-1.643, p= 0.001)	Implicates that transitions of care have potential to deter readmissions Patient level characteristics more predictive of readmission than hospital characteristics

			DV: 30-day readmission to acute care facility			○ ≥85 (OR: 1.504, CI: 1.069-2.115, p= 0.019) • Female (OR: 1.314, CI: 1.162-1.486, p= <0.0001) • Non-white (OR: 1.154, CI: 1.024-1.301, p= 0.020) • BMI > 40 (OR: 1.466, CI: 1.143-1.880, p= 0.003) • PVD (OR: 1.275, CI: 1.100-1.478, p= 0.002) • DM (OR: 1.219, CI: 1.083-1.372, p= 0.001) • Dialysis (OR: 1.311, CI: 1.015-1.693, p= 0.038) • Afib (OR: 1.652, CI: 1.370-1.992, p= <0.0001) • CHF (OR: 1.245, CI: 1.062-1.460, p= 0.007) • EF <40 % (OR: 1.222, CI: 1.044-1.431, p= 0.013) • Insurance type (range of OR: 0.657-1.248, CI: 0.488-1.535, p= 0.001-0.036) • Household income < $43,000 (OR: 1.158, CI: 1.030-1.302, p= 0.015)	
Maniar et al. (2014) **Level IV**	Retrospective cohort analysis Purpose: Prospectively identify risk factors for readmissions for patients undergoing cardiac surgery	N= 351 patients 249 patients for control group (not readmitted) and 102 patients as comparison group (readmitted in 30 days) All cardiac surgery	IV: Patient characteristics DV: readmission within 30-days of cardiac procedure	Readmission diagnosis	Frequency OR Multivariate logistic regression t-test or Wilcoxon test as alternative Chi-squared test and Fisher's exact	70 % of all readmission occurred between days 0-15 Multivariate regression findings: • COPD (OR: 2.00, CI 0.98-4.06, r^2= .24 p= 0.05) • Education level (OR: 0.52, CI 0.36-0.76, r^2= .21 p= 0.0001) • EF (OR: 0.80, CI 0.74-0.87, r^2= .15 p< 0.0001) • Previous cardiologist (OR: 0.41, CI 0.16-1.00, r^2= .22 p= 0.03)	Higher education levels, establishment with a physician and early discharge follow-up appear to be protective factors Single center experience with

		Single tertiary care institute				• Transplant/LVAD (OR: 2.37, CI 0.88-6.39, r^2= .31 p= 0.09) • LOS (OR: 1.56, CI 1.12-2.18, r^2= .28 p= 0.009) • Discharge location other than home (OR: 2.09, CI 1.11-3.92, r^2= .30 p= 0.02) • Seen by doctors early after discharge (OR:0.18, CI 0.11-0.31, r^2= .21 p< 0.0001)	limited sample size Early physician follow-up maybe protective from readmissions, however this study did not consider confounding variables, early follow-up not specific except defined prior to traditional 3-4 week follow-up visit

Pack et al. (2016)
 	
Level IV
	Retrospective cohort analysis
	
	Purpose: to create a predictive model that would estimate hospital readmission for both short (1 month) and medium-term (3 month) time frames in patients that undergo HVS
		N= 219 hospitals and 38, 532
		
		US hospitals January 2007-June 2011
		
		HVS patients only
			IV1: isolated AVS
			IV2: isolated MVS
			IV3: combination surgery
			
			DV: Readmission to hospital at any time
			
			Confounding variables: patient demographics, hospital characteristics.
				Reasons for readmission
				
				Patient characteristics
				
				Readmission at 1 month and 3 months
					Frequencies
					Proportions
					Mean, median, mode
					
					Chi-square and Kruskal-Wallis tests
					
					Wald-chi-squared
					
					Regression models
					
					OR
					
					95% CI
						7.8% and 12.8% readmitted at 1 and 3 months respectively
						
						Common reason: HF (12%), dysrhythmias (11%), and complications of procedure or care (11%)
						
						5 factors included in final predictive model:
						• Procedure (Wald $\chi 2$: 18.1)
						  ○ AV (reference)
						  ○ MV (OR & CI 1 month: 1.23, 1.12-1.36; OR & CI 3 month: 1.18, 1.09-1.28)
						  ○ Combination: (OR & CI 1 month: 1.38, 1.18-1.60; OR & CI 3 month: 1.26, 1.11-1.44)
						• LOS (Wald $\chi 2$: 39.3)
							The region of the hospital was the only significant hospital factor
							
							Only predictive for HVS patients
							
							Isolated MV or combination surgeries had a ~ 25% higher risk of readmission
							
							Similar risk factors in previous studies on CABG patients
							
							Nomogram developed for 3-month

						○ 1-5 days: Reference ○ 6-7 days: (OR & CI 1 month: 1.16, 1.00-1.35; OR & CI 3 month: 1.24, 1.10-1.40) ○ 8-12 days: (OR & CI 1 month: 1.35, 1.16-1.56 OR & CI 3 month: 1.44, 1.27-1.63) ○ 13+ days: (OR & CI 1 month: 1.78, 1.51-2.09; OR & CI 3 month: 1.80, 1.57-2.07) • Admission type: (Wald χ2: 26.1) ○ Emergent: (OR & CI 1 month: 1.21, 1.08-1.36; OR & CI 3 month: 1.37, 1.25-1.51) ○ Urgent/elective: reference • ESRD: (Wald χ2: 20.5) (OR & CI 1 month: 1.84, 1.50-2.26; OR & CI 3 month: 2.03, 1.70-2.43) • PRBCs (Wald χ2: 20.0) ○ 0: reference ○ 1-2: (OR & CI 1 month: 1.22, 1.07-1.39; OR & CI 3 month: 1.10, 0.99 -1.22) ○ 3-4: (OR & CI 1 month: 1.31, 1.14-1.50; OR & CI 3 month: 1.17, 1.04-1.31)	readmission risk→ may be useful for hospital participating in 90-day bundle payments

						○ 5+: (OR & CI 1 month: 1.46, 1.27-1.67; OR & CI 3 month: 1.32, 1.18-1.48)	
Redžek et al. (2015) **Level III**	Prospective analysis Purpose: determine the predictors for hospital readmission after open heart surgery	N= 1,268 patients Study period 1 year All cardiac surgery	IV1: Preprocedural factors IV2: Procedural factors IV3: Postprocedural factors DV: Readmission within 1 year	Readmission reason Patient demographics Procedural risk factors Post procedural risk factors	Frequency Mean and SD Kolmogorov-Smirnov Mann-Whitney U test Chi-squared Univariate and multivariate binary logistic regression OR	9.54% readmitted Reasons: HF (17.3%), sternal dehiscence (14.9%), dysrhythmia (14.9%), wound infection (11.6%), CP (11.6%), pericardial effusion (10.7%) Independent risk factors predictive of readmission: • Previous CVA p= 0.002 • Chronic HF p= < 0.0005 • Pericardial effusion p = 0.006	Single center Authors concluded if patient has pericardial effusion, should be closely monitored by cardiologist for at least six months
Shehata et al. (2013) **Level IV**	Retrospective study Purpose: determine if anemia at hospital discharge was associated with increased 30-day readmission for any reason	N= 2102 patients CABG and CABG/valve surgery Single center in Ontario	IV: Pre-discharge Hgb DV1: All cause readmission DV2: readmission due to cardiac causes DV3: increased mortality Confounding variables: patient demographics, indicators of hospital complications	Number and rate of readmissions Hgb concentration Patient characteristics Readmission reason	Mean and SD Chi-square Fisher's exact Univariable associations: Kruskal Wallis test Multivariable logistic regression models OR and 95% CI	Mean Hgb at discharge 10.21 ± 1.28 g/dL Univariable analysis: 30-day readmission and 30-day cardiac readmission respectively: • Hgb p = 0.009, NS • Age: p <0.001, p <0.001 • Female: p = 0.001, p= 0.03 • BMI: NS, p = 0.01 • LVEF < 20%: NS, p = 0.02 • Serum creatinine: 0.03, NS • Charlson comorbidity p <0.001, p <0.001 • Transfusion p <0.001, p= 0.01 • RBC transfusion p =0.002, p= 0.01	Lack of significant association between Hgb concentration and cardiac readmission rates Hgb significant in all cause readmission rates per univariable analysis Smaller sample size

						• Plasma transfusion, NS, p< 0.001 • Platelet transfusion NS, p < 0.001 • Moderate postoperative RF p < 0.001, p < 0.001 • IABP NS, p= 0.01 • Wound infection p <0.001, NS • LOS p= 0.006 , p= 0.02 <u>OR and CI intervals for multivariable analysis:</u> 30-day readmissions: • D/C Hgb: 0.99 (0.978-1.002) • Age: 1.02 (1.00-1.03) • Charlson comorbidity index 3-4: 2.3 (1.4-3.7) • Charlson comorbidity index 5+: 2.1 (1.26-3.6) • Postoperative RF: 1.4 (1.0-2.0) • Postoperative infection: 1.9 (1.2-3.0) 30-day readmission due to cardiac disease: • D/C Hgb: 0.99 (0.96-1.01) • Age: 1.1 (1.02-1.1) • Charlson comorbidity index 3-4: 4.6 (1.3-16.5) • Charlson comorbidity index 5+: 6.1 (1.646-22.5) • LVEF < 20% versus ≥ 50%: 3.2 (1.01-10.1 • Postoperative RF: NS • Postoperative infection: NS Mortality: • LVEF < 20% versus ≥ 50%: 23.0 (1.3-403.9)	Narrow CIs can indicate more precision

Shirzad et al. (2010)
 	
Level IV
	Retrospective analysis
	
	Purpose: determine the incidence of postoperative new onset AF in patient undergoing cardiac procedures and identify preoperative and perioperative factors with significant association of AF
		N= 15, 580 patients
		
		All cardiac surgery procedures
			IV1: Preoperative risk factors
			IV2: Operative risk factors
			
			DV1: New onset AF
				Patient characteristics
				
				Rates of AF
				
				Mortality
				
				Resource utilizations
				
				Readmission
					Mean and SD
					
					Frequencies and percentages
					
					Student *t* test
					
					Mann-Whitney *U* test
					
					Chi-squared
					
					Multivariable stepwise logistic regression
					
					Multivariable linear regression
					
					OR and 95% CI
						Independent predictors of AF after multivariate analysis: OR and CI
						• Age: p < 0.001
						  ○ ≤50: reference
						  ○ 51-60: 1.64 (1.343-2.004)
						  ○ ≥60: 2.306 (1.897-2.805)
						• RF 1.477 (1.004-2.173) p = 0.047
						• CHF 1.633 (1.398-1.907) p < 0.001
						• Beta-blocker 0.71 (0.612-0.824) p < 0.001
						• Operation type p < 0.001
						  ○ CABG: reference
						  ○ Valve: 4.074 (3.228-5.141)
						  ○ Combination: 2.122 (1.588-2.835)
						• Perfusion time 1.006 (1.004-1.008) p < 0.001
						• IABP 1.675 (1.26-2.229) p = 0.003
						
						AF effect of mortality and resource utilizations OR and CI:
						• Mortality 2.997 (1.952-4.602) p < 0.001
						• Readmission 1.456 (1.168-3.552) p < 0.001
							Patients with AF had higher readmission rates after adjusting for confounding variables
							
							Beta blocker had protective effect on AF
							
							73% of patient were male

Slamowicz et al. (2008) **Level IV**	Retrospective cohort analysis Purpose: To determine predictors of readmission after CABG	N= 6, 627 patients CABG only	IV: CABG surgery DV1: 7-day readmissions DV2: 30-day readmissions DV3: 6-month readmissions Confounding variables: age, gender, CCI, LOS, wait days	Readmission rates at 7 days, 30 days, and 6 months Patient characteristics Surgery characteristics	Logistic regression Frequencies Multivariate models 95% CI OR	Readmission within 7-days, 30-days, and 6 months respectively: 7.1%, 15.2 %, 32.3% Multivariate association OR and CI: Readmission at 7 days: • Age 1.01 (1.006-1.027) p = .03 • Single ED visit: 1.34 (1.05-1.71) p = 0.02 • Multiple ED visits: 1.75 (1.28-2.38) p < 0.01	Study period from 1998-2003 Similar findings compared to other studies Looked at ED visits (no other studies in this analysis has

						Readmission at 30 days: • Female 1.25 (1.06-1.46) p < 0.01 • CCI: 1.18 (1.11-1.24) p < 0.01 • LOS: 1.01 (1.00-1.03) p < 0.01 • Multiple ED visits: 1.53 (1.22-1.93) p < 0.01 Readmission at 60 days: • Age: 1.02 (1.02-1.03) p < 0.01 • CCI: 1.20 (1.15-1.26) p < 0.01 • LOS 1.03 (1.02-1.05) p < 0.01 • Multiple ED visits: 1.80 (1.49-2.18) p < 0.01	looked at ED visits)
Sun et al. (2008) **Level IV**	Retrospective cohort analysis Purpose: identify the preoperative characteristics and to define the risk predictors of readmission and preventative factors for readmission in low-risk CABG patients	N = 2,157 patients CABG only Single center study Study period January 2000-December 2005	IV: CABG Confounding factors: Preoperative factors, Intraoperative factors, Postoperative factors DV: readmission within 30 days after CABG	Patient characteristics Operation characteristics Readmission rates	Univariate analysis: Mean, SD, median, range, Student *t* test, Wilcoxon ran sum test, chi-square, Fisher's exact Multivariate analysis: OR, Hosmer-Lemeshow goodness-of-fit test, *C* statistic	6.3% of patients readmitted Incidence of early readmission: women 5.9% and men 6.3%, p > 0.05 Univariate analysis of postoperative characteristics: • PRBC: p=<0.01 • HLOS > 5 days: 25% (readmitted cohort) versus 17.4% (Not readmitted), p = 0.03 • ICULOS days: median readmitted cohort 1.00 (range 0.5-8.0) versus not readmitted 1.00 (0.29-38.3) p= 0.01 • Fewer readmitted patients received beta-blockers at discharge versus those not readmitted: 41.7% versus 50.7% respectively, p= 0.03	Only significant independent risk factors identified were preoperative DM and EBL during surgery Only studied low-risk patients

						- Fewer readmitted patients received ACE inhibitors at discharge versus those not readmitted: 8.1% versus 14.5% respectively, p = .04 Multiple logistic regression OR and CI: - Age: 1.01 (0.99-1.04) p = 0.20 NS - EBL: 1.00 (1.000-1.001) p = 0.05 - DM: 1.61 (1.08-2.42) p = 0.02 - HTN: 0.72 (0.50-1.04) p = 0.08 NS - Female: 1.08 (0.51-2.29) p = 0.84 NS - Postoperative AF: 1.12 (0.72-1.74) p = 0.63 NS - LOS > 5 days: 1.38 (0.89-2.13) p= 0.15 NS - Beta blocker at discharge: 0.81 (0.56-1.18) p= 0.27 NS - ACE inhibitor at discharge: 0.59 (0.31-1.13) p = 0.11 NS Reason for readmission: arrhythmia 23.1%, respiratory complications/PNA 18%, sternal infection 10.3%, MI or recurrent CP 10.3%, and pericardial drainage/tamponade 7.7%	

3VD- three vessel disease, AA- African American, AF-atrial fibrillation, ARF- acute renal failure, AV- aortic valve, AVS- aortic valve surgery, BMI-body mass index, CABG- coronary artery bypass graft, CCI- Charlson comorbidity index, CHF- congestive heart failure, CI-confidence interval, CMR-cardiac magnetic resonance, COPD- chronic obstructive pulmonary disease, CP- chest pain, CPB- cardiopulmonary bypass, CVA-cerebrovascular disease, D/C-discharge, DM- diabetes mellitus, DV- dependent variable, EBL- estimated blood loss, ED- emergency department, EF- ejection fraction, ESRD- end stage renal disease, Hct- hematocrit, HF- heart failure, Hgb- hemoglobin, HLOS-hospital length of stay, HR- hazard ratio, HTN-hypertension, HVS- heart valve surgery, Hx- history, IABP- intra-aortic balloon pump, ICU- intensive care unit, IP-inpatient, IV- independent variable, LOS- length of stay, LVAD- left ventricular assist device, LVEF- left ventricular ejection fraction, MI- myocardial infarction, MV-mitral valve, MVS- mitral valve surgery, NS- nonsignificant, OR-odds ratio, PCI-Percutaneous coronary intervention, PRBC- packed red blood cells, PVD- peripheral vascular disease, RF- renal failure, RVEF- right ventricular ejection fraction, SD- standard deviation, SE- socioeconomic status, SNF-skilled nursing facility, SR- systematic review, Sx- surgery, Tx-transplant, $\chi 2$- chi square

Appendix C.

Levels of Evidence as shown by Fineout-Overholt, Mazurek, Pmhnp, Stillwell, & Kathleen (2010) in *Evidence-based practice: Step by Step. Critical appraisal of the evidence: Part III.*

	Espinoza et al. (2016)	**Fasken et al. (2001)**	**Hannan et al. (2011)**	**Iribarne et al. (2014)**	**Lella et al. (2015)**	**Li et al. (2012)**	**Maniar et al. (2014)**	**Pack et al. (2016)**	**Redžek et al. (2015)**	**Shehata et al. (2013)**	**Shirzad et al. (2010)**	**Slamowicz et al. (2008)**	**Sun et al. (2008)**
Level I: Systematic review		X											
Level II: Randomized controlled trial													
Level III: Controlled trial without randomization				X					X				
Level IV: Case-control or cohort study	X		X		X	X	X	X		X	X	X	X
Level V: Systematic review of qualitative or descriptive studies													
Level VI: Qualitative or descriptive studies													
Level VII: Expert opinion or consensus													

Appendix D

Common Risk Factors Predicting 30-Day Readmission in Post-Cardiac Surgery Patients.

	Readmission Rate	**Demographic Factors**			**Comorbidity Factors**		**Hospitalization Course Clinical Factors**					**Procedure Factor**		
		RF 1. Female	**RF 2 Age > 70**	**RF 3. Af- Am**	**RF 4. BMI > 30**	**RF 5. DM**	**RF 6: Preop HCT**	**RF 7. EF < 35%**	**RF 8. Hyperglycemia > 200**	**RF 9: Post-op AF**	**RF 10: LOS**	**CPB Time > 100 mins.**	**Type of Procedures**	**Length of Surgery**
Espinoza et al. (2016)	**11.7%**					↑*	↑*		↑*	↑*		↑*		
Fasken et al. (2001)	**3.2%-30.6%**	↑		↑	**NS**						↑			
Hannan et al. (2011)	**16.5% (range 8.3%-21.1%)**	↑*	↑*	↑*	↑*	↑*					↑*			
Iribarne et al. (2014)	**18.7%**	↑*				↑*	↑*						**Combination sx ↑* LVAD/transplant ↑* Valve sx ↑***	↑*
Lella et al. (2015)								↑* **Right ventricular EF %** **Left Ventricular NS**						

Li et al. (2012)	**13.2%**	**↑***	**↑***	**↑* Race not specified**	**↑***	**↑***		**↑***		**↑***				
Maniar et al. (2014)	**Not specified**							**↑***			**↑***	**NS**		
Pack et al. (2016)	**7.8% 1 month 12.8% 3 months**						**↑ (units of blood received)**				**↑**		**↑**	
Redžek et al. (2015)	**9.54%**							**↑***						
Shehata et al. (2013)	**Not specified**	**↑***	**↑***				**↑ (postoperative hgb)**	**↑* (left ventricular)**			**↑***			
Shirzad et al. (2010)	**Not specified: RF reference occurrence of A-fib**		**↑***							**↑**			**↑***	
Slamowicz et al. (2008)	**7.1% at 7 days; 15.2% at 30 days and 32.3% at 6 months**	**↑* at 30 days**	**↑* at 7 days and 6 months**								**↑* at 30 days and 6 months**			
Sun et al. (2008)	**6.3%**	**↓ NS**	**NS**			**↑***				**NS**	**NS**			

$*p < 0.05$

AF= atrial fibrillation, BMI= body mass index, CPB= cardiopulmonary bypass, DM= diabetes mellitus, EF= ejection fraction, HCT= hematocrit, HGB= hemoglobin, LOS= length of stay, LVAD= left ventricular assist device, NS= non-significant, RF= risk factor