UNIVERSITY OF SAN DIEGO

Hahn School of Nursing and Health Science

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DOCTOR OF PHILOSOPHY IN NURSING

ADULT POSTOPERATIVE OPEN-HEART PATIENTS:
ANEMIA AND 30-DAY HOSPITAL READMISSION

By

Lindsey J. Ryan

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DOCTOR OF PHILOSOPHY IN NURSING

CANDIDATE'S

NAME: Lindsey J. Ryan

TITLE OF

DISSERTATION: Adult Postoperative Open-Heart Patients: Anemia and 30-Day Hospital Readmission

DISSERTATION

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Abstract

Background. In 2013 alone, more than 4% (3.9 million) of patients discharged from a hospital were readmitted. Anemia following a surgical procedure is associated with early hospital readmission.

Purpose/Aims. The following were specific aims of this dissertation:

- Aim 1. To develop an operational definition of the term *condition-based maintenance* as applied to health care and discuss the applicability and effectiveness of condition-based maintenance within health care.
- Aim 2. To identify the number of adult patients undergoing elective open-heart surgery with preoperative anemia.
- Aim 3. To examine the relationship between preoperative anemia, sociodemographics, and 30-day hospital readmission rates among postoperative open-heart adult patients.
- Aim 4. To explain the development and impact of the Hospital Readmissions Reduction Program (HRRP) and discuss the political, social, and economic implications of CABG as a newly targeted condition within the HRRP.

Approach. To address aim 1, the Walker and Avant model for concept analysis was used to review and analyze relevant literature, create a basic operational definition, and clarify related concepts. To address aims 2 and 3, a retrospective cross-sectional study was conducted using the STS Database to identify 1,353 surgical cases between August 2014 and July 2018. Cross-tabs and multivariable logistic regression analysis were used to assess the prevalence of preoperative anemia and association with 30-day hospital readmission. To address aim 4, a policy analysis was performed in accordance with Bardach and Patashnik's procedure.

Findings. From the concept analysis process, the notion of condition-based maintenance emerged, holding promise in advancing symptom science through development of personalized strategies to treat and prevent adverse symptoms of illness.

The prevalence of preoperative anemia was 43.7% ($n = 591$), and 177 (13%) had a 30-day hospital readmission. Patients with preoperative anemia had 1.88 (95% CI 1.36, 2.58) times higher odds of being readmitted. Through policy analysis, a correlation between insurance and 30-day hospital readmission following a CABG procedure was identified. Currently, penalty programs may be adjusted to better capture sociodemographic differences.

Implications. The findings from this study suggest preoperative anemia is associated with increased risk for 30-day hospital readmission. These results provide a basis for further risk reduction strategies and preoperative optimization.

Dedication

I dedicate this dissertation to my family. To my wonderful husband, Joel, for all your love, patience, and understanding. Thank you for believing in me and supporting my dream of achieving a doctorate. To my children, Noah, Kate, and Mina, you are my rock, my inspiration, my life. You can do whatever you dream with hard work and patience. Pray, work hard, and surround yourself with people who lift you up. To my supportive parents, whose encouragement has allowed me to succeed further than I ever would have imagined. Dad, I miss you still, and I long to be sitting in a boat with you on the lake. I know how proud you would be of my accomplishments, as always, and I take comfort knowing that I will one day see you again. To my siblings Casey and Corey, whose loving support (a.k.a. nagging) has continually given me the strength to persevere. From here on out, you will only address me as "Dr. Ryan." To my nieces and nephews: follow your dreams, stay positive and watch for open doors; you will do great things in this life! And to my amazing in-laws who have loved me from the start. Thank you for checking-in, indulging in conversations around my work, and praying. Ron and Gloria, thank you for allowing Joel and I to escape from time to time to keep our marriage going strong in the midst of a chaotic season. I know it isn't easy, and I appreciate your time, efforts, and patience.

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And last but not least, thanks to my employer, Sharp HealthCare, whose support of advanced education is nothing less than admirable. Thank you for making this possible. The knowledge I have gained is returned daily through my dedication to this exceptional organization and the community we serve.

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CHAPTER I

OVERVIEW

Background and Significance

In 2013, more than 4% (3.9 million) of patients discharged from a hospital were readmitted, costing the health care sector $52 billion (Fingar & Washington, 2015). Anemia following a surgical procedure has been associated with early hospital readmission (Merkow et al., 2015). However, identification of anemia in preoperative open-heart patients as an independent predictor of 30-day hospital readmission is unknown.

Decreasing readmissions among the postoperative coronary artery bypass graft (CABG) population through increased accountability efforts designated by the Hospital Readmission Reduction Program (HRRP) are likely to have profound effects similar to or perhaps greater than other established targeted conditions set by the Centers for Medicare and Medicaid Services (CMS). In fiscal year (FY) 2013, the maximum penalty for excess 30-day hospital readmission was set at 1%. The penalty increased to 2% in FY 2014 and reached a cap of 3% in FY 2015 that remains in place today. Historically, the health care system has taken extensive time to implement comprehensive programs to address patient outcomes.

Research Question and Aims

The purpose of this research study was to examine the prevalence and postoperative outcomes of preoperative anemia among adults undergoing open-heart surgery. To better understand this relationship, the research question of interest is, *What is the relationship between preoperative anemia (hemoglobin<13g/dL, for ⩾6 months)* *and 30-day hospital readmission among adult postoperative open-heart patients?* The following specific aims of this study were used to address the research question:

- Aim 1. To develop an operational definition of the term *condition-based maintenance* as applied to health care and to discuss the applicability and effectiveness of condition-based maintenance within health care.
- Aim 2. To identify the number of adult patients undergoing elective open-heart surgery with preoperative anemia.
- Aim 3. To examine the relationship between preoperative anemia, sociodemographics, and 30-day hospital readmission rates among postoperative open-heart adult patients.
- Aim 4: To explain the development and impact of the Hospital Readmissions Reduction Program (HRRP) and discuss the political, social and economic implications of coronary artery bypass grafting as a newly targeted condition within the HRRP.

Literature Review

Hospital Readmissions

The U.S. Patient Protection and Affordable Care Act (ACA) has forced hospitals to reexamine health care delivery with the initiation of the HRRP in 2012. Notably, the HRRP ties patient outcomes to reimbursement for care provided and allows the Centers for Medicare & Medicaid Services (CMS) to reduce reimbursement payments to hospitals with high readmission rates (CMS, 2016). Consequently, since the initiation of the HRRP, concentrated efforts have focused on the reduction of morbidity, as it has been shown to decrease costs (Keenan et. al, 2008). Interest in identifying readmission measures specifically related to surgical patients has grown.

Unplanned Readmissions

Unplanned readmissions to the hospital are increasingly being used as a quality metric of provider performance. Merkow et al. (2015) utilized a dataset from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQUIP) to examine the timing and reason for unplanned readmissions. This prospective study captured 498,875 patients from 346 ACS NSQUIP associated institutions who underwent bariatric surgery, colectomy, proctectomy, hysterectomy, total hip/knee arthroplasty, ventral hernia repair, and lower extremity vascular bypass in 2012. Across all procedural groups, 5.7% had an unplanned readmission with an average length of stay of 1 day and a median time to readmission of 8 days. Surgical site infection was the leading cause of readmission (19.5%) with ileus or intestinal obstruction as the second (10.3%). Bleeding and anemia were analyzed together, making up the third leading cause of readmission at 4.3% (Merkow et al., 2015). Kassin et al. (2012) found a much higher rate of readmission (11.3%) among 1,442 general surgery patients admitted between 2009 and 2011 at a single academic center. Findings showed an occurrence of postoperative complications was most closely associated with 30-day hospital readmission (Kassin et al., 2012). While this data is only representative of the surgical procedures it examined, it provides a baseline with which to compare other surgical procedures.

Cardiac Surgery

Open-heart surgery yields a very high index cost of more than $149,000 and has an associated length of stay averaging 9.2 days (Mozaffarian et al., 2016). Historically, readmission related to cardiac surgery has been significantly high (13-18%) and has yet to waiver (Hannan et al., 2011; Sargin et al., 2016). In 1999, a multihospital study examined rates and common causes of hospital readmission in patents who underwent coronary artery bypass graft surgery in New York. This was the first study of its kind (Hannan et al., 2003). Upon examination of the identified diagnosis-related groups (DRGs), surgical site infection was listed as the top cause of readmission (28%), followed by heart failure (16%). Anemia was identified as the primary cause of hospital readmission in just 0.5% of all cases (Hannan et al., 2003). Compared to Merkow et al. (2015) who noted a 5.7% readmission rate across six other identified surgical procedures, the average rate of hospital readmission among the open-heart surgery group was 12.9% (Hannan et al., 2003). What is not known is how many patients with a primary diagnosis of heart failure were also anemic or iron-deficient. Iron-deficiency with or without anemia plays a substantial role in the prognosis of heart failure that is often left untreated.

In a retrospective study with 2,664 patients, Sargin et al. (2016) compared CABG procedural outcomes with an alternate method for myocardial revascularization, percutaneous coronary intervention (PCI), and found there was no statistically significant difference in 30-day hospital readmissions (18.3% and 15.2%, respectively). Although several risk factors for readmission were identified through multivariate analysis, anemia was not taken into consideration and thus would not have been identified as a risk factor.

Hospital readmissions, particularly following cardiac surgery, are costly to both the patient and the organization providing service. In a 2009 study in Regione Piemonte, Italy, 2,067 open-heart patients were monitored during their stay and for six months following their procedure. The purpose was to examine ICU interventions and patient conditions using hazard models and regression analysis to identify DRGs that may predict hospital readmission and reimbursement costs. Zadra and Caruso (2015) found of the patients monitored, 528 (25.5%) had at least one hospital readmission event. Factors during the index hospitalization identified as strong prognosticators of a hospital readmission included length of stay, tracheostomy, heart or kidney failure, infection, and the use of intra-aortic balloon pumps (IAPB) or extracorporeal membrane oxygenation (ECMO) machines (Zadra & Caruso, 2015). Identification of specific treatments and therapies as they relate to the predictability of hospital readmission is an important contribution to the working knowledge of hospital readmission prediction models.

Predictive Models

One strategy to improve morbidity and reduce hospital readmission is to first identify patients who are potentially at high-risk. Nashef et al. (1999) first published the European System for Cardiac Operative Risk Evaluation (EuroSCORE) in 1999. This evaluation instrument has aided cardiothoracic surgeons in surgical decision-making, preoperative informed consent, quality assurance, and health care management (Yap et al., 2006). The validity of the EuroSCORE has been tested in tens of thousands of patients and across other countries such as Spain, Turkey, and Australia. While some studies have found the validity to be satisfactory, overestimation of mortality among high-risk patients has been consistent, requiring clinicians and researchers to continue to work on finding a more meaningful method of risk evaluation.

Researchers in Columbia considered adding hemoglobin and B-type natriuretic peptide (BNP) to the EuroSCORE to see if the predictive power of morbidity and mortality would be increased for both index hospitalizations and 60-day readmissions. Hernández-Leiva, Dennis, Isaza, and Umaña (2013) reviewed data on 554 patients, looking at the predictability of hemoglobin and BNP independently against the EuroSCORE, then they incorporated the variables into the EuroSCORE itself. Findings showed either high preoperative BNP or low hemoglobin are associated with independent risk of postoperative outcomes. When both variables were integrated into the EuroSCORE, an increase in the prediction of morbidity was noted; however, the prediction of mortality was insignificant. A study published in 2013 described a comparison analysis between the EuroSCORE, EuroSCORE II, and the Society of Thoracic Surgeons (STS) risk models on Turkish patients undergoing coronary artery bypass grafting procedures. Findings indicated an overestimation of mortality using the EuroSCORE II; in contrast, the EuroSCORE and STS models estimated mortality well (Kunt et al., 2013).

Espinoza et al. (2016) published a simplified risk prediction instrument, the 30-Day Readmission Score, to improve the identification of patients who are high-risk for an early hospital readmission following open-heart surgery. The instrument was tested and validated in Argentina on more than 5,000 patients (AUC 0.639 [95% CI 0.606 to 0.672]). The risk prediction included a review of the hematocrit value preoperatively, with a value of <35% preoperatively considered high-risk. Other variables included a history of diabetes mellitus, minutes spent on-pump, highest serum glycemic level, and atrial fibrillation postoperatively. The authors admitted to poor exploration of preoperative anemia and discussed the association between acute kidney injury (AKI) and anemia, with supporting evidence that AKI is a precursor to other risk factors associated with hospital readmission. Based upon multivariate analysis results, neither preoperative renal failure nor postoperative acute kidney injury were strongly associated with hospital readmission. However, upon examination of preoperative anemia alone, uni- and multivariate analysis showed significant associations with hospital readmission (Espinoza et al., 2016).

Anemia Definition and Prevalence

The World Health Organization (WHO) provided a definition of anemia in 1968 as a hemoglobin <13g/dL for males and <12g/dL for non-pregnant females, all 15 years and older and measured at sea level (Cappellini & Motta, 2015; Shander & Roy, 2016; WHO, 2015). This definition is broken down further by the WHO to describe three differentiating levels of anemia: mild (men 11.0-12.9g/dL; women 11.0-11.9g/dL), moderate (8.0-10.9g/dL) and severe (<8.0g/dL), respectively. Iron deficiency is a common global issue that, if left untreated, may lead to anemia (WHO, 2011). Multiple chronic medical conditions are attributed to iron deficiency, including chronic kidney disease, Parkinson's disease, inflammatory bowel disease, rheumatoid arthritis, and heart failure (HF; Toblli, Cao, Rivas, Giani, & Dominici, 2016). Cardiac muscle depends on iron for metabolism and mitochondrial function.

Le (2016) reported a prevalence rate of anemia in the U.S. population (excluding pregnant women) at 5.6%, with 1.5% meeting criteria for moderate-severe anemia.

Anemia was higher in non-pregnant females compared to males (7.6% vs. 3.5%) with the exception of persons 80–85 years, where twice as many males had anemia (26.3% vs. 15.2%). The prevalence of anemia among hospitalized patients was high (10.4%). Over a 10-year period, from 1999-2008, the rate of hospitalized patients with anemia climbed steadily and continues to increase (Kim, Connell, McGeorge, & Hu, 2015; Rachoin, Cerceo, Milcarek, Hunter, & Gerber, 2013).

Preoperative Anemia

Throughout various studies, investigators have consistently found the prevalence of preoperative anemia to be much higher (22%-54.4%) than that of the general hospitalized patient population (10.4%; Hung, Besser, Sharples, Nair, & Klein, 2011; Karkouti, Wijeysundera, Beattie, & Reducing Bleeding in Cardiac Surgery (RBC) Investigators, 2008; Rachoin et al., 2013). Preoperative anemia has been identified as an independent prognosticator of postoperative adverse events. Clinical evidence, as stated in the literature, associates preoperative anemia with adverse outcomes such as increased transfusions, perioperative death, and prolonged length of stay (Gupta et al., 2013; Hallward, Balani, McCorkell, Roxburgh, & Cornelius, 2016; Hung et al., 2011; Karkouti et al., 2008; Rachoin et al, 2013). A large study conducted at Veteran's Affairs from 1995-2005 examined 36,658 patients who underwent on-pump CABG surgery. Results showed a strong association between hemoglobin and serum creatinine, with serum creatinine being the stronger predictor of adverse postoperative outcomes (Bell et al., 2008). These studies however, failed to examine the relationship between postoperative anemia and hospital readmission.

The prevalence of preoperative anemia in patients undergoing cardiac surgery ranges from 26% to 35% (Karkouti et al., 2008; Kulier et al., 2007). Older adults aged 80–85 years had the highest proportion of anemia (19.4%) and moderate-severe anemia (4.0%; Le, 2016). Considering octogenarians make up approximately 8% of cardiac surgery cases and are increasingly being referred, it is imperative to consider anemia during the preoperative assessment (Wang et al., 2014).

Preoperative Anemia Treatment

Studies have shown administration of intravenous (IV) iron can provide protection for heart tissue and prevent structural remodeling (Dong et al.,2005; Naito et al., 2009). Ferric carboxymaltose (FCM), a relatively new IV medication that has been shown to increase hemoglobin in patients undergoing elective orthopedic surgeries, has also been linked to much lower incidence of administration-related adverse events compared to traditional oral iron supplements (Rineau, Chaudet, Carlier, Bizot, & Lasocki, 2014). Similar results were found in a study conducted with patients diagnosed with colon cancer; Calleja et al. (2016) found preoperative administration of FCM effectively reduces the need for red blood cell transfusion and reduces length of stay for patients undergoing elective surgery.

Dowidar, Ezz, El Dorf, and Kasem (2016) examined the effects of combined supplementation methods on hematocrit using oral iron and recombinant human erythropoietin (rHuEPO) as an intervention. Participants were patients undergoing an elective myomectomy procedure and were randomly assigned to three groups: control, oral iron, and oral iron with rHuEPO injections. Researchers noted a reduction in blood product transfusion among patients who received oral iron and rHuEPO injections. Both

FCM and rHuEPO show promising results for cardiac surgery patients and future research should examine effectiveness of these treatments among cardiac surgery patients. Currently, limited literature exists with mixed findings.

Theoretical Framework

It is important to understand how anemia may develop, the impact of chronic anemia on the human body, and the symptoms a patient may experience as a result. This study was informed by the physiological processes of chronic anemia and was supported by symptom burden theory (Gill, Chakraborty, & Shelby, 2012).

Symptom Burden: Etiology

The term *symptom* was first known to be used in 1541 and is derived from late medieval Latin *synthoma*, based on Greek *sumptōma* ("chance, symptom") from *sumpiptein* ("happen"). A current definition includes "a physical or mental feature that is regarded as indicating a condition of disease, particularly such a feature that is apparent to the patient" (Symptom, n.d.). As a noun, *burden* is defined as "a duty or misfortune that causes hardship, anxiety, or grief; a nuisance." The first known use of the Middle English term came prior to the 12th century, from "Old English *byrthen*; akin to Old English *beran* ("to carry"; Burden, n.d.).

Symptom Burden: Operational Definition

Efforts to define *symptom burden* have largely focused around the oncology patient. Cleeland (2007) defined symptom burden as "the sum of the severity and impact of symptoms reported by a significant proportion of patients with a given disease or treatment" (p. 17). Gill et al. (2012) took a different approach and were the first to conduct a study asking oncology patients to provide a definition themselves. A total of 58 patients identified what symptom burden meant to them personally, in addition to rating their perceived symptom burden during the previous week. After analysis of the participants' responses, a definition for symptom burden was identified as "a loss of functional abilities along with psychological suffering, both are affected by the impact of specific severe symptoms" (2012, p. 88). The definitions of symptom burden used among the oncology population are increasingly being used in patients suffering from chronic illness. Bekelman et al. (2009) found patients with symptomatic heart failure had the same, if not worse, symptom burden, depression, and spiritual well-being compared to patients with advanced cancer. In this study, symptom burden is defined as "the subjective, quantifiable prevalence, frequency, and severity of symptoms placing a physiologic burden on patients and producing multiple negative, physical, and emotional patient responses" (Gapstur, 2007).

Conceptual Framework

Anemia and Cardiac Remodeling

To better understand how anemia may lead to symptomatic heart failure and ultimately open-heart surgery, a review of the pathophysiology is provided.

Decrease in red blood cell production & oxygen delivery. Patients with chronic kidney disease, low iron, or vitamin deficiency are at increased risk for low red blood cell production. With decreased red blood cell production, oxygen-carrying capacity is limited.

Compensatory state. Over time, low iron stores may lead to cardiac remodeling, including left ventricular (LV) hypertrophy, dilation, and diastolic dysfunction (Jankowska, von Haehling, Anker, Macdougall, & Ponikowski, 2012; Toblli et al., 2016).

It has been suggested there is increased generation of reactive oxygen and nitrogen species among patients with heart failure. This oxidative/nitrosative stress may contribute to cardiac remodeling within the myocardium and ultimately lead to contractile failure (Madungwe, Zilberstein, Feng, & Bopassa, 2016). This remodeling compromises hemodynamics (increased blood volume, heart rate, stroke volume, and decreased afterload) and contributes to cardiac inflammation and fibrosis, leading to symptomatic heart failure with pulmonary congestion (Naito et al., 2009).

Symptom burden. Patients with heart failure face several challenges leading to a decreased quality of life. As physical symptoms increase in severity, functional status decreases, hospital admissions increase, and psychological well-being diminishes (Alpert, 2017; Buck et al., 2015). Patients may undergo open-heart surgery to improve symptoms through coronary revascularization, repair of valve regurgitation, and stenosis (Figure 1.1).

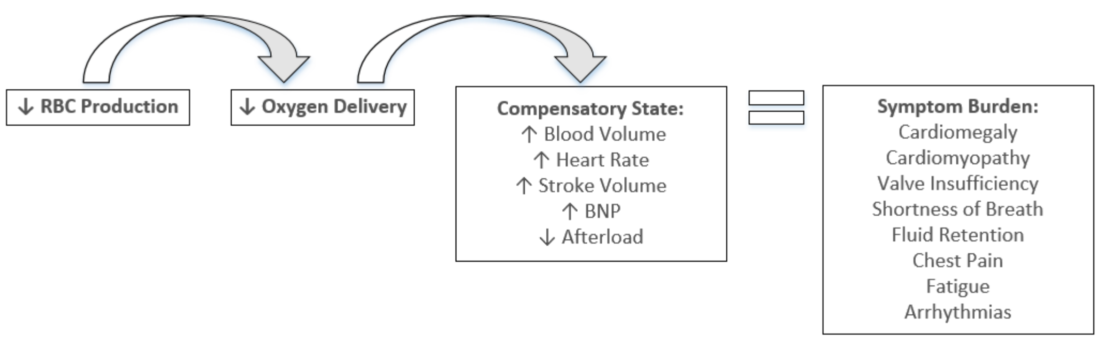

Figure 1.1. Conceptual framework: Anemia and heart failure symptom burden.

Dissertation Approach Overview

Papers providing a concept analysis, empirical study, and a policy analysis form the basis of this dissertation and are presented in Chapters 2, 3, and 4 respectively.

Paper I: Concept Analysis

Chronic illness burdens patients, providers, and health care organizations. To confront this challenge, the National Institute of Nursing Research emphasizes the importance of identifying biological indicators, understanding the behaviors of symptoms, finding symptom precursors, and creating management algorithms. To support these aims, the Walker and Avant model for concept analysis was used to review and analyze relevant literature, create a basic operational definition, and clarify related concepts. From this analysis, *condition-based maintenance* emerged as a novel concept, holding promise in advancing symptom science through the development of personalized strategies to treat and prevent the adverse symptoms of illness.

Paper II: Multisite, Cross-Sectional Study

Anemia is linked to structural and functional cardiac dysfunction. As patients become burdened with symptoms, they are more likely to be referred to a cardiothoracic surgeon for structural repair of the heart. The purpose of this study was to describe the relationship between preoperative anemia (hemoglobin <13g/dl) and 30-day hospital readmission among adult postoperative open-heart patients.

A retrospective, observational, cross-sectional study was conducted using the Society of Thoracic Surgeons National Database for Adult Cardiac Surgery to identify 1,353 surgical cases between August 2014 and July 2018. Although retrospective studies are often criticized for their unmeasured confounding variables and bias, special care was taken to avoid such issues. This design allowed the investigator to identify whether adult patients who have preoperative anemia prior to elective open-heart surgery are at greater risk for an adverse outcome, namely a 30-day hospital readmission, compared to those without preoperative anemia. Data extracted allowed the investigator to describe the relationship between elective open-heart surgical outcomes and sociodemographics across three community hospitals in San Diego County. Lastly, the study design allowed for examination of the prevalence and relative risk of preoperative anemia among adult patients undergoing elective open-heart surgery.

Sample and sampling. Identifiers were provided through a cross-sectional sample taken between August 2014 and July 2018 of cases having undergone open-heart surgery at any of three acute care not-for-profit hospitals that are part of a multicenter health care system located in southern California. Cases were extracted from the Society of Thoracic Surgeons National Database for Adult Cardiac Surgery.

Inclusion criteria.

1. Persons 18 years of age and older
    a. Persons less than 18 are excluded as the majority of open-heart surgical procedures during this timeframe are related to congenital defects.
2. Elective or urgent surgery
    a. *Elective surgery* is defined as a procedure that is scheduled in advance because it does not involve a medical emergency.
    b. *Urgent* is defined as a surgery that must be done to preserve the patient's life, but does not need to be performed immediately.
3. Open-heart surgery procedure(s)
    a. Frequently conducted procedures include coronary artery bypass grafting, mitral valve repair/replacement, aortic valve repair/replacement, and any combination of the above.

Exclusion criteria.

1. Emergent surgery
    a. Emergent open-heart procedures naturally carry a higher risk of morbidity and mortality both in-hospital and post-discharge.
2. Infrequent open-heart surgical procedures
    a. Infrequent procedures such as tricuspid valve repair/replacement and pulmonary valve repair/replacement are excluded as they are associated with significant early and late mortality.
3. Previous heart transplant
    a. A transplanted heart increases the risk of an adverse outcome in patients undergoing CABG or valve replacement due to several factors (e.g. increased scar tissue, decrease immune function).
4. Known congenital heart defect
    a. Congenital heart defect, repaired or unrepaired, increases the risk of an adverse outcome in patients undergoing CABG or valve replacement.
5. Died prior to discharge

Procedures. Cases were extracted from the Society of Thoracic Surgeons National Database for Adult Cardiac Surgery for only the three participating facilities, with surgeries between August 2014 and July 2018. The primary investigator validated the completeness and quality of the abstracted data by validating a random sample of cases. Cases included in the study were followed long enough for the outcome of interest to occur. The outcome is independent of health care personnel judgment, since patient reported outcomes (e.g., 30-day hospital readmission, and death) are reported separately.

Measurement. Table 1.1 presents the variables measured in the study.

Table 1.1

Study Variables

	Variable Name	Data Type
1	Patient Age	Continuous
2	Patient Gender	Categorical
3	Patient Zip Code	Categorical
4	Race Ethnicity	Categorical
5	Hospital Name	Categorical
6	Primary Payor	Categorical
7	Primary Payor Medicare Fee for Service	Categorical
8	Admit Source	Categorical
9	Body Mass Index	Continuous
10	Diabetes	Categorical
11	Dyslipidemia	Categorical
12	Hypertension	Categorical
13	Tobacco Use	Categorical
14	Prior Cerebrovascular Accident	Categorical
15	Preoperative Anemia – 4 Classifications	Categorical
16	Preoperative Anemia – 2 Classifications	Categorical
17	Hemoglobin	Continuous
18	Last Creatine Level	Continuous
19	Total Albumin	Continuous
20	Last A1c Level	Continuous
21	Previous Cardiac Intervention	Categorical
22	Prior Myocardial Infarction	Categorical
23	Cardiac Presentation Symptoms on Admission	Categorical
24	ADP Inhibitors within 5 days	Categorical
25	Aspirin within 5 days	Categorical
26	Glycoprotein IIb/IIIa Inhibitor within 24hrs	Categorical
27	Anticoagulants within 48hrs	Categorical
28	Warfarin/Coumadin within 5 days	Categorical
29	Factor Xa Inhibitors within 5 days	Categorical
30	Novel Oral Anticoagulant within 5 days	Categorical
31	Thrombin Inhibitors within 5 days	Categorical
32	Thrombolytics within 48hrs	Categorical
33	Ejection Fraction	Continuous
34	Surgery Status Elective / Urgent	Categorical
35	Urgent Reason	Categorical
36	Perioperative Blood Products	Categorical
37	**Perioperative Red Blood Cell Units**	**Categorical**

Table 1.1 (continued)

	Variable Name	Data Type
38	Perioperative Fresh Frozen Plasma Units	Categorical
39	Perioperative Platelet Units	Categorical
40	Perioperative Cryoprecipitate Units	Categorical
41	Perioperative Antifibrinolytic Caproic Acid	Categorical
42	Perioperative Antifibrinolytic Tranexamic Acid	Categorical
43	Coronary Artery Bypass	Categorical
44	Cardiac Pulmonary Bypass Utilization	Categorical
45	Valve Procedure	Categorical
46	Aortic Valve	Categorical
47	Aortic Valve Procedure	Categorical
48	Mitral Valve	Categorical
49	Mitral Valve Procedure	Categorical
50	Postoperative Peak Glucose	Continuous
51	Postoperative Creatinine Level	Continuous
52	Postoperative Hemoglobin	Continuous
53	Postoperative Blood Products	Categorical
54	Postoperative Red Blood Cell Units	Categorical
55	Postoperative Fresh Frozen Plasma Units	Categorical
56	Postoperative Platelet Units	Categorical
57	Postoperative Cryoprecipitate Units	Categorical
58	Initial Intensive Care Unit Hours	Continuous
59	Readmission to Intensive Care Unit	Categorical
60	Postoperative Intra-Aortic Balloon Pump	Categorical
61	Postoperative Sternal Superficial Wound Infection	Categorical
62	Postoperative Deep Sternal Infection Mediastinitis	Categorical
63	Postoperative Conduit Harvest	Categorical
64	Postoperative Wound Intervention Procedure	Categorical
65	Postoperative Renal	Categorical
66	Postoperative Renal Dialysis	Categorical
67	Postoperative Dialysis Required After Discharge	Categorical
68	Postoperative Cardiac Arrest	Categorical
69	Postoperative Atrial Fibrillation	Categorical
70	Mortality 30day Status	Categorical
71	Discharge Location	Categorical
72	Readmission 30day Hospital	Categorical
73	Readmission Reason 30day Discharge	Categorical
74	Total Operating Room Time	Continuous
75	Admission to Discharge Length of Stay	Continuous
76	Surgery to Discharge Length of Stay	Continuous
77	**Total Intensive Care Unit hours**	**Continuous**

Analysis. Aim 1 of the study was to identify the number of adult patients undergoing elective open-heart surgery with preoperative anemia. The primary endpoint is the prevalence of adult patients identified as having preoperative anemia (Hb <13g/dL) prior to open-heart surgery. Aim 2 of the study was to examine the relationship between preoperative anemia, sociodemographics, and 30-day hospital readmission rates among postoperative open-heart adult patients. The endpoint for this aim is the risk of 30-day hospital readmission following open-heart surgery among adult patients with preoperative anemia compared to those without.

Descriptive statistics were used to identify frequencies of variables. The number and rate of readmissions within 30-days of hospital discharge were first identified. Stratification by surgical procedure, comorbid illnesses, sex, age, ethnicity, and zip code followed. The hemoglobin concentrations were used as both continuous and categorical variables (i.e., <8g/dL, 8-10g/dL, 10.1-12.9g/dL, and ≥13 g/dL). Univariable associations between primary and secondary categorical variables and the hemoglobin concentration was assessed using the chi-square test or Fisher's exact test as appropriate. Univariable associations for continuous variables were assessed using the analysis of variance. The variables found on univariable analysis to be significantly associated with the categorical outcomes were then included in multivariable logistic regression models. All reported *p*-values are two-tailed, and a 0.05 significance level was used in final models.

Paper III: Policy Analysis

Open-heart surgery yields a very high index cost, more than $149,000 and has an associated length of stay averaging 9.2 days. Compared to all condition readmissions, CABG patients had the second highest average Medicare payment per readmission at

$8,136 per visit for an annual cost of $151 million. Implementation of the U.S. Patient Protection and Affordable Care Act (ACA) in 2010 provided government agencies with structures and processes to hold hospitals accountable for improving the quality of care delivered while reducing the associated astronomical health care costs.

The aims of this policy analysis were two-fold: (a) to explain the development and impact of the Hospital Readmission Reduction Program (HRRP) and (b) discuss the political, social, and economic implications of coronary artery bypass grafting as a newly targeted condition within the HRRP. Peer-reviewed literature was gathered using PubMed and CINAHL databases. The paper is presented in accordance with Bardach and Patashnik's eight-step policy analysis procedure. Additional information was retrieved from AARP, AHRQ, CMS, Commonwealth Fund, DHHS, HRSA, Kaiser Family Foundation, and the Library of Congress.

Human Subjects

Human subject protection oversight was provided by the Institutional Review Board of both the University of San Diego and the participating health care system. To safeguard obtained information, data were stored on a restricted, password-protected computer system.

Implications for Nursing

Organizations providing open-heart surgery must be prepared to redesign their programs to incorporate additional services (such as predictive models and care transitions programs) upstream to prevent negative downstream consequences such as hospital readmissions. Increased interprofessional collaboration will provide patients with enhanced comprehensive care throughout their hospitalization, even following them home, thus optimizing patient recovery. Nurses, including clinical nurse specialists (CNSs), must be empowered to maximize their practice, creating a structure where care can be rendered effectively and efficiently throughout the patient's stay.

Summary

Since the initiation of the HRRP, concentrated efforts focusing on the reduction of morbidity and readmissions have pushed hospitals to implement risk reduction programs at a much quicker pace, and results show favorable outcomes in decreased costs and improved quality of life (Keenan et. al, 2008). Through the addition of CABG as a targeted measure, it can be expected that readmission rates will decrease. However, sociodemographic data must be taken into consideration because many patients will present with multiple comorbidities and poor compliance, thus challenging what variables and outcomes are truly within the control of health care providers.

CHAPTER II

MANUSCRIPT #1

Application of Condition-Based Maintenance in Health Care: A Concept Analysis

Lindsey J. Ryan

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Abstract

Chronic illness burdens patients, providers, and health care organizations. To confront this challenge, the National Institute of Nursing Research emphasizes the importance of identifying biological indicators, understanding the behaviors of symptoms, finding symptom precursors, and creating management algorithms. To support these aims, the Walker and Avant model for concept analysis was used to review and analyze relevant literature, create a basic operational definition, and clarify related concepts. From this research, the notion of condition-based maintenance emerged as a novel concept, holding promise in advancing symptom science through the development of personalized strategies to treat and prevent the adverse symptoms of illness.

Keywords: condition-based maintenance, concept analysis, readmission, symptom science, predictive models.

Statement of Significance

The condition-based maintenance model is simple and underpinned by the premise most equipment failures are preceded by certain signs, conditions, or indications. Research shows condition-based maintenance improves equipment health management, lowers life cycle costs, and prevents failures from occurring. Application of equipment-related condition-based maintenance has been widely researched throughout various industries; however, use of condition-based maintenance has not been explored in relation to health maintenance among humans.

This article advances the NINR's focus on symptom science through the development of personalized strategies to treat and prevent the adverse symptoms of illness. It is anticipated this concept analysis will contribute to further identification of clinical signs of deterioration and accompanying interventions to prevent hospitalization and unnecessary death.

Application of Condition-Based Maintenance in Health Care: A Concept Analysis

Introduction

In 2013, more than 4% of patients (3.9 million) discharged from a hospital were readmitted, costing the health care sector $52 billion.[1] The U.S. Patient Protection and Affordable Care Act (ACA) has forced hospitals to reexamine health care delivery with the initiation of the Hospital Readmission Reduction Program (HRRP), which ties patient outcomes to reimbursement for care provided. In November 2012, the Centers for Medicare & Medicaid Services (CMS) began to reduce reimbursement payments to hospitals with high readmission rates.[2]

In 2013, the National Institute of Nursing Research[3] charged a group of symptom science experts with identifying research questions that could be used to advance nursing science. Experts discussed the importance of identifying biological indicators, understanding the behaviors of symptoms, finding symptom precursors, and creating management algorithms. In addition, experts strongly recommended leveraging technologies to improve symptom management and change the chronic illness trajectory through innovative care delivery models. When deriving a concept for analysis related to the topics of symptom science and hospital readmissions, concepts and models were examined from a wide range of industries that dealt with the general ideas of *maintenance* and *failure* within their field. Articles within engineering were overwhelmingly filled with various maintenance models. These models were examined and the lifespan of equipment and related maintenance was closely reviewed and compared to the health care delivery model (Figure 2.1).

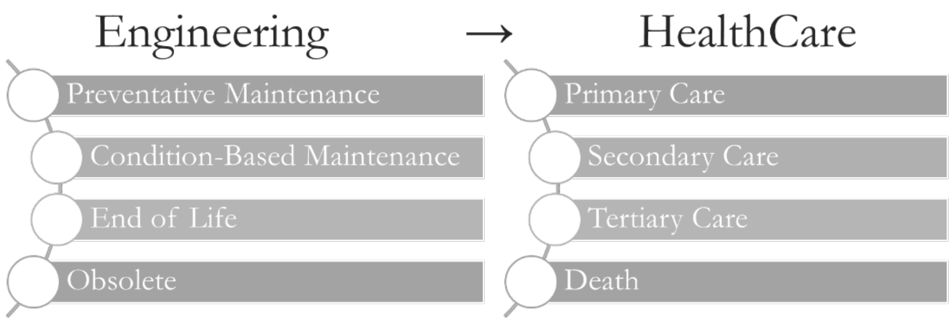

Figure 2.1. Concept derivation from the engineering industry to health care.

Condition-based maintenance originated in the 1940s when the Rio Grande Railway Company crafted the model to detect coolant and fuel leaks in a diesel engine's lubricating oil. Due to the overwhelming success of the model, the U.S. Army adopted and improved upon initial efforts, propelling the models popularity during the ‘50s, ‘60s, and ‘70s.[4] The condition-based maintenance model is simple and underpinned by the premise most equipment failures are preceded by certain signs, conditions, or indications.[5] Research shows condition-based maintenance improves equipment health management, lowers life cycle costs, and prevents failures from occurring.[6] Application of equipment-related condition-based maintenance has been widely researched throughout various industries; however, condition-based maintenance has not been explored in relation to health maintenance in humans. Application of the condition-based maintenance model may prove relevant in reducing hospital readmission as it relates to the monitoring, identification, and treatment of specific disease processes before an individual experiences a significant decline in health, warranting care.

Objective

The purpose of a concept analysis is to examine a particular term, carve out a clear definition, and ultimately describe its application within an identified context. The aim of this concept analysis paper is two-fold. The first aim is to develop an operational definition of *condition-based maintenance* as applied to health care; the second is to discuss the applicability and effectiveness of condition-based maintenance within health care.

Method

The paper is presented in accordance with Walker and Avant's[7] eight-step concept analysis procedure: (a) selecting a concept; (b) determining the aim and purpose of the analysis; (c) identifying the uses of the concept; (d) defining the attributes of the concept; (e) constructing a model case example; (f) creating borderline, related, and other case examples; (g) identifying the antecedents and consequences; and (h) defining the empirical referents.

Literature was gathered using the PubMed, Wiley Interscience Journals, and Emerald databases. Over 420 articles were identified from the initial search for the years 2010 through 2017 using the term *condition-based maintenance*. Limiters were applied that included full-text, peer-reviewed articles that were available in English, narrowing the volume of pertinent literature to 54 articles. Each article was then retrieved and reviewed for the definition, use, and key concepts of condition-based maintenance. Cited reference lists were also examined to identify additional relevant literature, resulting in six additional articles for a total of 60 articles reviewed. Of all the articles reviewed, 56 referenced the concept of condition-based maintenance and were used for further analysis.

Results

Uses of the Concept

While literature from the field of engineering prevails, condition-based maintenance can also be found in automotive, aviation, defense, and manufacturing industries. *Condition* is a familiar term within health care literature, often referring to a patient's state of being. Condition is also frequently referenced within engineering and manufacturing industries to describe the state or order in which a piece of equipment exists.[8] In the field of sports medicine, *condition* is used within the context of training or acclimatizing a person physically,[9] while in the field of law, *condition* is viewed as the essence of a contract.[10] Recent literature explores the barriers of adapting condition-based maintenance to other industries (e.g. steel-making, chemical processing). Although condition-based maintenance has practical application within health care, no published literature could be found applying the concept to the monitoring of human health conditions. To gain a firm understanding of condition-based maintenance, the definitions of *condition*, *based*, and *maintenance* will be examined both independently and together.

Condition. The Middle English noun *condition* is derived from the 14th century Old French term *condicion,* a derivative of the Latin *condicio,* meaning "terms of agreement." *Condition* is defined as:

- "a usually defective state of health"
- "a way of living or existing"
- "the state in which something exists: the physical state of something"

- "the physical or mental state of a person or animal"
- "a premise upon which the fulfillment of an agreement depends" [11]

Based. According to Merriam-Webster, the word *based* was first known to be used in the 13th century. The adjective is Middle English, originally derived from the Greek *bainein,* meaning "to go." Definitions include

- **"**the bottom or lowest part of something: the part on which something rests or is supported"
- "something (such as a group of people or things) that provides support for a place, business, etc."
- "a main ingredient to which other things are added to make something"
- "the fundamental part of something"
- "something on which something else is established" [12]

Maintenance. *Maintenance*[13] (noun) dates to the mid-14th century from an Old French term *maintenir*, meaning "action of providing a person with the necessities of life." Definitions for the modern term include

- "the combination of all technical and associated administrative actions intended to retain a system in a state in which it can perform its required function"[14]
- "all technical and managerial actions taken during usage period to maintain or restore the required functionality of a product or an asset"[15]

Condition-based maintenance. *Condition-based maintenance*, also known at the time as *predictive maintenance*, was first introduced by the Rio Grande Railway

Company in the late 1940s.[4] Over time, slight variations of the definition have evolved and can be found throughout the literature:

- "monitoring one or more indicators of asset condition that can be used to give warning of asset deterioration sufficiently in advance of failure so that there remains time to take preventive action"[16]
- "a decision-making strategy where the decision to perform maintenance is reached by observing the condition of the system and/or its components"[17]
- "a set of maintenance actions based on real-time or near real-time assessment of equipment condition, which is obtained from embedded sensors and/or external tests & measurements taken by portable equipment'[18]
- "a maintenance policy which does maintenance actions before product failures happen, by assessing product condition including operating environments, and predicting the risk of product failures in a real-time way, based on gathered product data"[15]

In this paper, *condition-based maintenance* is defined as an efficient, proactive process utilizing monitoring methods to predict, identify, and repair health-related problems precisely, therefore extending one's life.

Defining Attributes

Walker and Avant[7] describe attributes as the characteristics most often related with the concept, differentiating the concept from other associated concepts. Through the exploration of identified attributes, condition-based maintenance can then be distinguished from other types of maintenance. Four primary attributes were identified following a review of the literature: predictive, proactive, precise, and efficient (Table 2.1).

Table 2.1

Attributes of Condition-Based Maintenance

Sources	Number of Attributes	Predictive	Proactive	Precise	Efficient
Abdul Rahman, *et al.,* 2013	1 of 4	+			
Abou-El-Seoud & Matsui, 2014	3 of 4	+	+		+
Abou-El-Seoud, *et al.,* 2012	3 of 4	+		+	+
Ahmad & Kamaruddin, 2012	2 of 4	+			+
Altosole, *et al.,* 2014	3 of 4	+		+	+
Baglee, *et al.,* 2016	3 of 4	+	+		+
Baraldi, *et al.,* 2013	1 of 4			+	
Bousdekis, *et al.,* 2015	4 of 4	+	+	+	+
Byon, 2013	2 of 4			+	+
Byon, *et al.,* 2011	1 of 4	+			
Corodón, *et al.,* 2011	1 of 4	+			
de Jonge, *et al.,* 2017	2 of 4	+		+	
Dong, *et al.,*2013	2 of 4	+		+	
Eker & Camci, 2013	2 of 4	+			+
Feng, *et al.*, 2015	1 of 4	+			
Grasso, *et al.,* 2014	2 of 4	+			+
Greenough & Grubic, 2011	1 of 4				+
Guan, *et al.*, 2013	2 of 4	+			+
Guo, *et al.,* 2016	2 of 4	+			+
Huang, 2010	1 of 4	+			
Hussain, 2015	2 of 4			+	+
Jayaswal, *et al.,* 2013	3 of 4	+		+	+
Jiang, *et al.,* 2012	3 of 4	+		+	+
Kamei & Takai, 2011	1 of 4	+			
Khodabakhshian, 2013	3 of 4	+	+		+
Kisić, *et al.*, 2015	3 of 4	+		+	+
Last, *et al.*, 2011	2 of 4	+			+
Lee & Ni, 2015	4 of 4	+	+	+	+
Lee, *et al.,* 2014	1 of 4				+
Lee, *et al.,* 2015	2 of 4	+			+
Li, *et al.*, 2014	3 of 4	+	+		+
Li, *et al.,* 2015	1 of 4				+
Liu, *et al.*, 2012	1 of 4			+	
Lubini & Fuamba, 2011	3 of 4	+		+	+
Meyer & Adams, 2013	1 of 4	+			
Naderkhani & Makis, 2015	2 of 4		+		+
Pack, 2014	3 of 4	+	+		+

Table 2.1 (continued)

Sources	Number of Attributes	Predictive	Proactive	Precise	Efficient
Prajapati & Ganesan, 2013	3 of 4	+		+	+
Rasaienia, *et al.,* 2013	2 of 4	+		+	
Safari, *et al.,* 2010	2 of 4			+	+
Shin & Jun, 2015	4 of 4	+	+	+	+
Shinkai, *et al.,* 2013	1 of 4				+
Tarefder, *et al.,* 2013	1 of 4	+			
Terpening, *et al.,* 2016	3 of 4	+		+	+
Thompson, 2010	2 of 4	+		+	
Van & Bérenguer, 2012	2 of 4	+			+
Van Dam & Bond, 2015	2 of 4	+	+		
Wang, *et al.,* 2014	1 of 4		+		
Wu, *et al.,* 2013	2 of 4	+			+
Xia, *et al.,* 2011	2 of 4	+			+
Xiang & Coit, 2014	2 of 4	+			+
Xu, *et al.,* 2012	1 of 4	+			
Yakub, *et al.,* 2012	2 of 4	+		+	
Zhang, *et al.,* 2010	4 of 4	+	+	+	+
Zhou, *et al.,* 2014	2 of 4	+			+
Zhu, *et al*., 2015	1 of 4		+		

Predictive. Literature containing the use of *predictive* in relation to condition-based maintenance defines the term in an analytical, prognostic fashion. Through application of condition-based maintenance, the end-user, or clinician, can gather monitored data, analyze the findings, and in turn predict future failures or life expectancy.[19,20] Within health care, predictive models have been used for disease management considering they stratify risk and increase the optimization of clinical resource utilization. Several condition-based maintenance algorithms, or decision support systems, exist today to guide the end-user, or provider, in identifying appropriate responses related to data findings.[21] With the ability to make informed decisions, interventions are only provided if deemed necessary to prevent failures, or deterioration, from occurring.[22,23]

Proactive. In a technologically savvy world, there are many opportunities to use or develop a proactive solution to identified problems. With the case of condition-based maintenance, having a monitoring process in place allows the end user to not only predict but also proactively repair deteriorating systems before they advance to a state of failure.[21,24] For example, if predictive measures indicated an individual with congestive heart failure was deteriorating based on increased weight and shortness of breath, a provider could proactively intervene, preventing unnecessary stress for the individual and a potential visit to the emergency department.

Precise. The success of condition-based maintenance lies in the ability of the concept to be precise in predicting deterioration. Just as an engineer intimately understands how a specific piece of equipment works, a provider should also have a complete understanding of the patient clinically to accurately set up predictive measures and precise treatment should deterioration occur.[25]

Efficient. The use of condition-based information has fewer associated costs than other concepts that do not monitor deterioration.[25] In contrast to planned maintenance models, where maintenance is performed based upon predefined scheduled intervals, condition-based maintenance is performed only when deterioration is detected.[26] Condition-based maintenance lengthens the span of time between repairs, or office visits, reducing unnecessary maintenance activities that cost time, money, and manpower. Currently, health care in the United States most closely resembles the structure of a planned maintenance model, where patients are scheduled for predetermined office visits. From infancy through adulthood, preventative care recommendations are made outlining when patients should see their providers and undergo certain tests and procedures. While these recommendations are largely evidence-based, the goal of catching disease through predetermined screening activities may be costlier in cases where only a very small fraction of the population will become ill in the absence of preventive measures.

Constructed Cases

Model case. Mrs. Jones is an 81-year-old female who had an aortic valve repair (AVR) six days ago. Today's labs revealed a hemoglobin and hematocrit of 11/29 respectively and her cardiac echogram ejection fraction was 36%, previously 32% during surgery. Mrs. Jones was started on 20mg furosemide daily and weekly erythropoietin injections (*predictive*). As she prepared for discharge, she received verbal instructions from both her primary nurse and cardiac surgeon. In addition to the printed discharge materials, Mrs. Jones was provided an SpO2 monitor (*monitor and analyze deterioration data*) and explicit instructions for use with successful return demonstration (*proactive*). Four days after Mrs. Jones was discharged home from the hospital, she notices a weight gain of five pounds and her SpO2 monitor is reading 94%, down from her usual 98% (*abnormal data values*). Throughout the day, Mrs. Jones' legs feel noticeably "heavier" and she experiences difficulty catching her breath when walking. That afternoon, her daughter visits for lunch, listens to her mother's concerns, notes the symptoms she is having, and rechecks her SpO2 that reads 93%. Mrs. Jones' daughter assists her in calling her primary care provider. The physician asks specific questions related to her cardiac function then instructs Mrs. Jones to take an additional 20mg of furosemide each day and calls in a prescription for an angiotensin-converting-enzyme inhibitor (ACEI; *precise & efficient*). The following morning, Mrs. Jones notes a weight loss of two pounds and a decrease in her shortness of breath and leg swelling. Mrs. Jones is able to reduce her clinic visits and stay out of the hospital due to the at-home monitoring process set in place (*increased safety; decrease burden and costs*). Mrs. Jones' health is stable and she is able to enjoy life with her family and friends (*life extension*).

This scenario is a model case because it includes all four critical attributes and exemplifies the identified definition of condition-based monitoring. The provider predicts the patient may have complications following surgery based on objective data gathered in the hospital. This prompts the provider to proactively set up a process through which the patient can be monitored for signs of deterioration long before a crisis occurs. When the patient begins deteriorating, the provider asks precise questions and responds with a precise and efficient treatment to meet the needs of the patient. Overall, this process is efficient; it was handled quickly over the phone and kept the patient from deteriorating further and needing an appointment, or worse, re-hospitalization.

Borderline case. Claire is a type II diabetic who used the last of her long-acting insulin this morning. Claire placed a call to her primary care provider and left a voicemail requesting renewal of her prescription (*precise*). Mid-morning, her primary care provider calls in the prescription to Claire's identified pharmacy on file then calls Claire to close the loop and notify her the prescription has been placed (*efficient*).

In this borderline case, only two of the four attributes are represented. Claire has a chronic condition she is being treated for and could have predicted her need for additional insulin. Indeed, Claire could have proactively reached out to her primary care provider before running out of insulin to prevent a potential health crisis.

Contrary case. Jed wakes up feeling as though he is coming down with a cold. The next day he is short of breath, diaphoretic, and has an increased work of breathing.

Jed's wife drives him to the local emergency department, where he is admitted. After multiple tests and procedures, Jed is diagnosed with congestive heart failure.

This is a contrary case, as it does not contain any of the attributes associated with the concept. Jed became acutely ill to where he could not predict or proactively treat. Due to his various symptoms, emergency department providers ordered multiples tests and procedures related to their constructed dual diagnoses. This episode of health care delivery, while appropriate, was neither precise nor efficient.

Antecedents

The conditions and events that precede a concept are labeled *antecedents*.[7] In relation to condition-based maintenance, two antecedents have been identified in the literature: monitor and analyze deterioration data, and abnormal data values (Figure 2.2).[15,16]

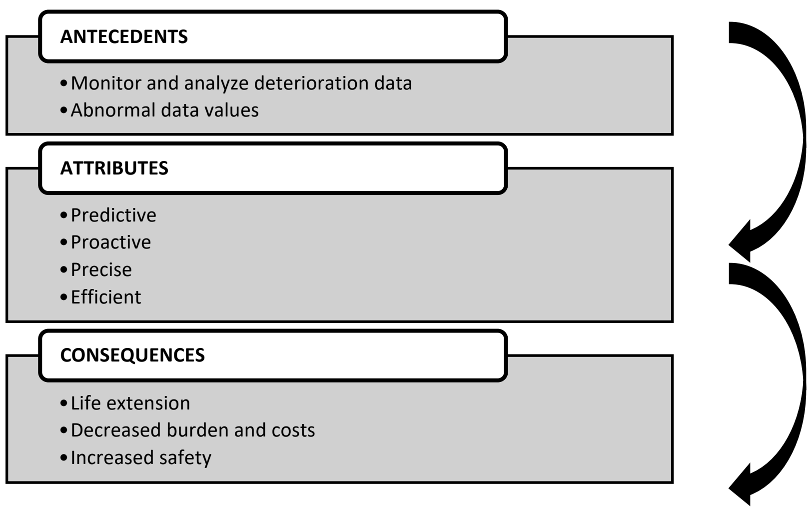

Figure 2.2. Antecedents, defining attributes, and consequences of condition-based maintenance.

A structure and process must be in place to monitor and analyze data to detect deterioration. Monitored data points can then be gathered and analyzed to better predict whether or not deterioration is detected. Deterioration is identified through abnormal values and predicts not only whether a maintenance intervention is required to proactively prevent an episode of failure, but also estimated life expectancy.[17]

Consequences

Subsequent events that occur as a result of the concept are labeled *consequences*.[7] Throughout the literature, three positive consequences are consistently identified as a result of condition-based maintenance: life extension, decreased burden and costs, and increased safety.

Asset life may be extended with the use of condition-based maintenance because it essentially prevents failure from occurring. As a result, there is both better utilization of the asset's life and a reduction in maintenance cost.[25] Application of condition-based maintenance also leads to a decrease in burden and costs.[27] As data are gathered from the monitoring process, early indication of deterioration can be identified and proactive, and precise maintenance can then be performed. Safety is increased when an asset is identified as deteriorating and proactive and precise maintenance is performed to prevent failure.[26]

Empirical Referents

The attributes of condition-based maintenance—predictive, proactive, precise, and efficient—can be measured quantitatively. In reviewing the literature, several instruments were identified (e.g., the electronic vibration measurement instrument).[28] Unfortunately, all identified instruments are specific to the monitoring of equipment and are not transferrable to monitoring human conditions. Considering the attributes along with the antecedents and consequences, there are a number of ways to create applicable instruments within the health care industry. Instrument construction must be disease specific since the monitoring and analyzing of deterioration data would be unique to specific diseases.

Discussion

This analysis emphasizes the importance of symptom science through the transposing and trialing of established monitoring methods to improve patient safety, increase life-span, and decrease burden and health care costs. This concept analysis is considered innovative; nonetheless, it is also abstract in nature. Without applicable empirical referents, further research is needed to identify if condition-based maintenance can be adapted to monitoring various human conditions effectively. Additional quantitative and qualitative research focusing on both disease-specific measurements and quality of life components could further develop the concept in becoming more concrete. Outcomes from this analysis may be useful in the development and testing of measurement instruments.

Relevance to Clinical Practice

Condition-based maintenance advances the NINR's[29] focus on "developing personalized strategies to treat and prevent the adverse symptoms of illness across diverse populations and settings." Clarifying the concept of condition-based maintenance may lead to improved assessment practices through early identification of symptom precursors, optimization of symptom dynamics, and prevention of symptom relapse or clinical deterioration.

In this concept analysis, condition-based monitoring is explored and defined within the context of the health care industry to further advance symptom science efforts. An abundance of literature on condition-based monitoring exists; however, research focusing on the application of the concept within health care is limited. Through the identification of antecedents, attributes, and consequences, health care providers may begin to investigate the translation of this concept into clinical practice. Constructed cases demonstrating the presence and absence of the attributes are provided to enhance the understanding of condition-based monitoring as a concept. Empirical referents are proposed to enhance recognition of this abstract concept and measure defining attributes in the future.

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CHAPTER III

MANUSCRIPT #2

Preoperative Anemia and 30-Day Hospital Readmission
Among Adult Postoperative Open-Heart Patients:
A Multisite Cross-Sectional Descriptive Study

Lindsey J. Ryan

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Abstract

Background: Anemia is linked to structural and functional cardiac dysfunction. As patients become burdened with symptoms, they are more likely to be referred to a cardiothoracic surgeon for structural repair of the heart.

Objective: The purpose of this study was to describe the relationship between preoperative anemia and 30-day hospital readmission among adult postoperative open-heart patients.

Methods: A retrospective, cross-sectional study was conducted using the Society of Thoracic Surgeons National Database for Adult Cardiac Surgery to identify 1,353 surgical cases between August 2014 and July 2018. Descriptive, bivariate, and inferential statistics were used to describe the sample, examine relationships between variables, and identify the overall prevalence of anemia. Binomial logistic regression was used to assess the association with 30-day hospital readmission with preoperative anemia and sociodemographics.

Results: Among the 1,353 open-heart surgery cases, approximately three quarters were male (n = 964, 71.2%); prevalence indicated 762 (56.3%) had no anemia, 373 (27.6%) had mild anemia, 210 (15.5%) had moderate anemia, 8 (0.6%) had severe anemia, and 177 (13.5%) were readmitted to the hospital within 30 days of discharge. Preoperative anemia (Fisher's $\chi^2 = 21.3$, $p < .001$) was significantly associated with 30-day hospital readmission. Logistic regression indicated that patients with severe preoperative anemia were 14.29 (95% CI 1.21, 167.9) times more likely to be readmitted to the hospital within 30 days of discharge.

Discussion: The findings from this study suggest severe preoperative anemia is associated with increased risk for 30-day hospital readmission. These results provide a

basis for further risk reduction strategies and preoperative optimization. Guidelines should be reviewed to include treatment of preoperative anemia and evaluation of reverse cardiac remodeling for prognosis.

Preoperative Anemia and 30-Day Hospital Readmission Among Adult Postoperative Open-Heart Patients: A Multisite Cross-Sectional Descriptive Study

Introduction

Preoperative anemia is a common yet modifiable preoperative finding associated with adverse perioperative and postoperative events, increased 30-day morbidity, and mortality (Burton et al., 2018; Burton et al., 2019; Dai et al., 2018; Jabagi et al., 2018; Karkouti, Wijeysundera, & Beattie, 2008; Nuis et al., 2013). Studies suggest the prevalence of preoperative anemia in patients undergoing cardiac surgery is higher than most surgeries, ranging from 13% to 67% (Dai, et al., 2018; Hubert et al., 2019; Karkouti et al., 2008; Kulier et al., 2007; Musallam et al., 2011; Nuis et al., 2013). In the United States, octogenarians hold the highest prevalence of anemia (19.4%) and moderate-severe anemia (4.0%), with up to 41% diagnosed with anemia in preoperative cardiac surgery cases (Carrascal et al., 2010; Le, 2016). Considering octogenarians make up approximately 8% of cardiac surgery cases and are increasingly being referred, it is imperative to take anemia into consideration during the preoperative assessment (Wang et al., 2014).

The impact of preoperative anemia on morbidity and mortality has been well documented in the general surgery population. Patients with preoperative anemia are more likely to have lengthy hospitalizations and increased ventilatory days and are more likely to receive allogenic transfusions, each of which is associated with an increased risk of morbidity and mortality (Najafi & Faraoni, 2015; Ranucci et al., 2012; Shander, Knight, Thurer, Adamson, & Spence, 2004). Patients presenting with severe preoperative anemia have an expected mortality rate of 14% (Ranucci et al., 2012). Nonetheless, little is known about the association between preoperative anemia in open-heart surgery patients on 30-day hospital readmission. The purpose of this multi-center cross-sectional study was to retrospectively examine the relationship between preoperative anemia (hemoglobin, hb < 13g/dL) and 30-day hospital readmission among adult postoperative open-heart patients. The specific aims were:

- Aim 1: Estimate the prevalence of preoperative anemia among adults seeking urgent or elective open-heart surgery.
- Aim 2: Examine the relationship between preoperative anemia, sociodemographics, and 30-day hospital readmission rates among postoperative open-heart adult patients.

Methods

Study Design and Data Collection

Study oversight was conducted by the institutional review boards of both the participating health care system and university. Retrospective data were extracted using the Society of Thoracic Surgeons (STS) National Database for Adult Cardiac Surgery. This reputable database is a prospective clinical outcomes registry designed to provide organizations and clinicians with benchmarked risk-adjusted outcomes (D’Agostino et al., 2018). With more than 30 years of data collection and 6.5 million record entries, researchers have and continue to develop meaningful quality and safety improvements in cardiac surgery worldwide (Badhwar et al., 2018). Registry data includes anonymized demographics, admission sources, preoperative risk factors, laboratory and medication data, perioperative variables, and postoperative outcomes for patients undergoing cardiac surgery. Data managers are trained by the STS through online modules and a mentorship program. Data managers manually extract patient information from multiple sources using a standardized worksheet provided by the STS. Patient information is then transcribed from the worksheet into the registry via vendor software (STS, 2019). For this study, the investigator used data from August 2014 through July 2018 gathered from three southern California community hospitals. The initial extraction yielded 5,047 cases. Cases were subsequently removed from the sample if the patient had (a) a known prior CABG or valve-related procedure, (b) emergency surgery requiring immediate intervention, (c) concurrent atrial fibrillation procedure, (d) undergone a tricuspid or pulmonic valve procedure, (e) died during hospitalization, (f) preoperative diagnosis of cardiogenic shock, and (g) lacked a preoperative hemoglobin value. Following the exclusions, 1,353 cases with patient data for X number of variables were used for the main analysis.

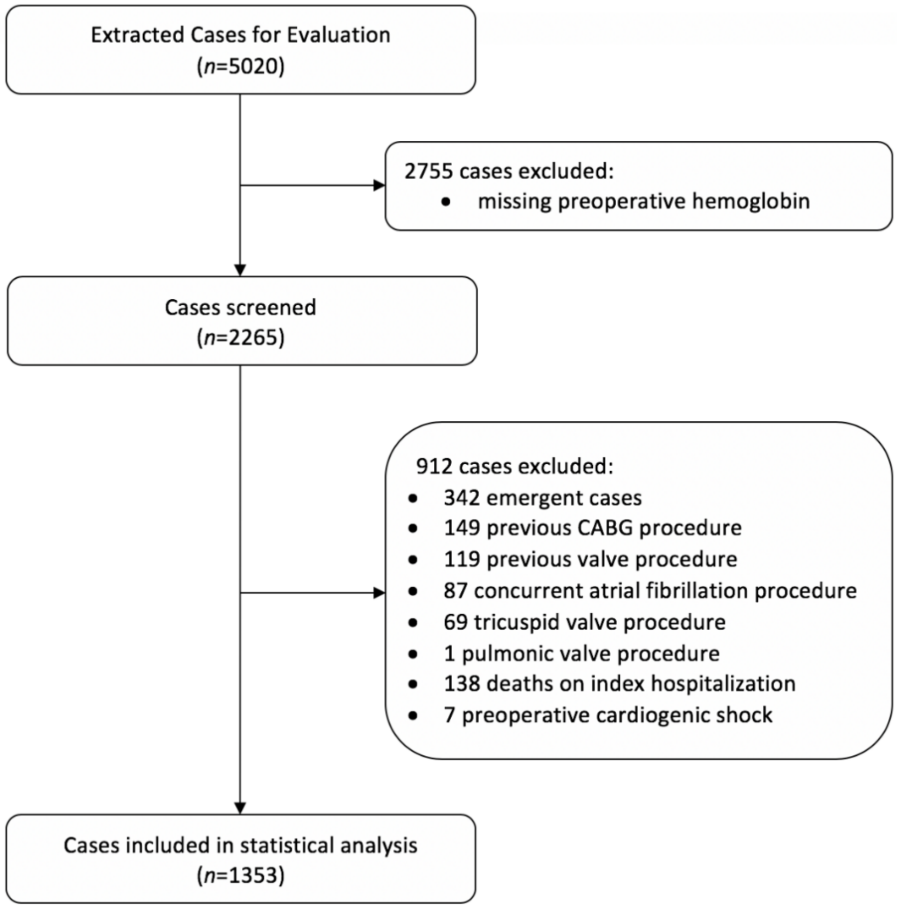

Figure 3.1. Consort diagram.

Procedures

In 1968, the World Health Organization (2015) provided an operational definition of anemia as a hemoglobin < 13g/dL for males and < 12g/dL for non-pregnant females. For this study, preoperative anemia was defined as a hemoglobin concentration of less than 13g/dL for both men and women. Patients with anemia were further divided into three classes: mild anemia (hb 10.1-12.9 g/dL), moderate anemia (hb 8-10g/dL), and severe anemia (hb < 8g/dL; WHO, 2015). Preoperative anemia was identified by the last hemoglobin measurement prior to the index operation. The postoperative outcome of 30-day hospital readmission included all cause readmissions.

Statistical Analysis

Descriptive statistics were calculated for all variables and data were analyzed for normality, missing values, and outliers. Bivariate analyses (chi-square, Fisher's exact, One-way between groups Analysis of Variance) were used to examine the relationships between patients' sociodemographic characteristics, preoperative risk factors (including preoperative anemia), intraoperative factors, postoperative factors, and 30-day hospital readmission. Variables significant at $p < .05$ in the bivariate analysis were considered for entry in a multivariate logistic regression model to ascertain factors that increase the odds of 30-day hospital readmission among postoperative open-heart adult patients. Variables at $p < .25$ known to be of clinical importance based on the extant literature (Hannan et al., 2011; Hernández-Leiva, Dennis, Isaza, & Umaña, 2013; Kassin et al., 2012; Merkow et al., 2015) were also considered for entry into the logistic regression model. A less traditional *p* level can help identify variables that by themselves are not significantly associated with the outcome but may play an important role in the presence of other variables (Bursac, Gauss, Williams, & Hosmer, 2008). A total of 34 out of over 80 potential predictors were identified at the $p < .25$ level in the bivariate analysis. To evaluate the role of each variable considered for entry into the logistic regression model, multiple logistic regression models were run removing, one-by-one, those non-significant variables at $p < .10$ that were not confounders (Exp(B) < 20%). A change in the parameter estimate greater than 20% indicates the removed variable is important in that it provides an adjustment for one or more of the variables remaining in the model (Bursac et al., 2008). After considering all 34 variables, the final two models included those variables that remained significant at the .05 level and additional variables that were not statistically significant but were considered *a priori* to be important determinants of 30-day hospital readmission risk (Bursac et al., 2008; Hosmer & Lemeshow, 2000). All statistical analyses were carried out using IBM SPSS software version 25.0.

Results

Sociodemographic and clinical characteristics of study participants by anemia severity are presented in Tables 3.1 and 3.2; sociodemographic and clinical characteristics of study participants overall and by 30-day hospital readmission are presented in Tables 3.3 and 3.4. Among the 1,353 patients who underwent open-heart surgery, approximately three quarters were male (71.2%, *n* = 964), 44.1% (*n* = 573) were White, non-Hispanic, and 76.6% (*n* = 397) had Medicare as their primary insurance payor. Primary admission source was evenly distributed for elective admission (49%, *n* = 663) and admission through the emergency department (44.1%, *n* = 597). Notable comorbidities included diabetes (47.3%, *n* = 640), dyslipidemia (86%, *n* = 1164), hypertension (87.1%, *n* = 1,177), and tobacco use (48.6%, *n* = 654). Seven-hundred and sixty-two (56.3%) patients had no anemia, 373 (27.6%) had mild anemia, 210 (15.5%) had moderate anemia, and 8 (0.6%) had severe anemia. Finally, 177 (13.5%) were readmitted to the hospital within 30-days after discharge.

Preoperative Anemia

Bivariate analyses (chi-square and Fisher's exact tests for association) were conducted to evaluate the relationship between categorical variables and preoperative anemia severity (no anemia, mild anemia, moderate anemia, severe anemia) for postoperative open-heart adult patients (Tables 3.1 and 3.2). A complete list of the 60 categorical variables evaluated can be found in Appendix A. The level of significance was set to $p < .05$. There was a statistically significant difference between preoperative anemia severity and gender ($\chi^2(3) = 116.25$, $p < .001$, *Cramer's V* = .293; small effect), zip code, race, hospital name, admission source, diabetes, dyslipidemia, hypertension, prior myocardial infarction, cardiac presentation, ADP inhibitors within 5-days, anticoagulants within 24-hours, surgery status (elective or urgent/emergent), urgent surgery reason, intraop blood products ($\chi^2(3) = 162.44$, $p < .001$, *Cramer's V* = .339; moderate effect), intraop blood products: RBC units ($\chi^2(3) = 226.18$, $p < .001$, *Cramer's V* = .330; moderate effect), intraop blood products: FFP units, intraop blood products: Platelet units, postop blood products, postop blood products: RBC units, postop blood products: FFP units, intraop Epsilon-aminocaproic acid, intraop Tranexamic acid, cardiopulmonary bypass utilization, mitral valve procedure, readmission to intensive care unit, postop renal impairment, postop other cardiac arrest, postop other atrial fibrillation, 30-day hospital readmission, and discharge location (Tables 3.1 and 3.2).

Table 3.1

Sociodemographic Characteristics of Study Population by Severity of Preoperative Anemia (N = 1,353)

			Preoperative Anemia Severity[a]									
	Total		No Anemia		Mild		Moderate		Severe			
Characteristic	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*	χ^2	*p*
Gender											116.25	< .001
Female	389	28.8	131	33.7	169	43.4	87	22.4	2	0.5		
Male	964	71.2	631	65.5	204	21.2	123	12.8	6	0.6		
Race											68.17	< .001[b]
White, non-Hispanic	573	44.1	377	65.8	133	23.2	60	10.5	3	0.5		
Hispanic, Latino	358	27.6	163	45.5	104	29.1	87	24.3	4	1.1		
Black, African American	32	2.5	10	31.3	11	34.4	11	34.4	0	0.0		
Asian, Pacific Islander	146	11.2	71	48.6	52	35.6	23	15.8	0	0.0		
Other	189	14.6	101	53.4	64	33.9	23	12.2	1	0.5		
Zip Code											37.21	.024[b]
San Diego Co.: Central	172	12.8	78	45.3	53	30.8	37	21.5	4	2.3		
San Diego Co.: East	448	33.4	248	55.4	126	28.1	72	16.1	2	2.7		
San Diego Co.: North Central	184	13.7	119	64.7	46	25.0	19	10.3	0	0.0		
San Diego Co.: North Coastal	21	1.6	14	66.7	6	28.6	1	4.8	0	0.0		
San Diego Co.: North Inland	102	7.6	72	70.6	19	18.6	10	9.8	1	1.0		
San Diego Co.: South County	332	24.7	179	53.9	96	28.9	56	16.9	1	0.3		
Out of Co.: East	37	2.8	18	48.6	14	37.8	5	13.5	0	0.0		
Out of Co.: North	33	2.5	19	57.6	9	27.3	5	15.2	0	0.0		
Out of State	13	1.0	8	61.5	3	23.1	2	15.4	0	0.0		
Hospital											40.98	< .001[b]
Hospital A	334	24.7	155	46.4	107	32.0	69	20.7	3	0.9		
Hospital B	430	31.8	223	51.9	128	29.8	78	37.1	1	0.2		
Hospital C	589	43.5	384	65.2	138	23.4	63	10.7	4	07		

Table 3.1 (continued)

Characteristic	Total *n*	Total %	No Anemia *n*	No Anemia %	Mild *n*	Mild %	Moderate *n*	Moderate %	Severe *n*	Severe %	χ^2	*p*
			Preoperative Anemia Severity[a]									
Admission Source											72.74	< .001
Elective admission	663	49.0	429	64.7	178	26.8	52	7.8	4	0.6		
Emergency department	597	44.1	289	48.4	171	28.6	135	22.6	2	0.3		
Transfer from hospital or acute care facility, or other admission source	93	6.9	44	47.3	24	25.8	23	24.7	2	2.2		
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***F***	***p***
Age	64.16	11.00	62.99	10.49	66.24	10.63	64.87	12.64	59.63	13.07	8.13	< .001[c]
BMI	28.86	5.83	29.32	5.66	28.98	6.32	27.08	5.17	27.33	6.37	9.78	< .001[c]

Note. BMI = Body Mass Index; Co. = County; *F* = One-Way ANOVA unless otherwise specified; *M* = Mean; *SD* = Standard Deviation; χ^2 = Fisher's Exact Test unless otherwise specified. [a]Preoperative Anemia Severity: No-anemia (hb ≥ 13 g/dL), mild anemia (hb 10.1-12.9 g/dL), moderate anemia (hb 8-10g/dL), and severe anemia (hb < 8g/dL). [b]Monte Carlo Sig. (2-sided). [c]Welch Sig. (2-sided).

One-way between groups Analysis of Variance (ANOVA) was conducted between continuous variables and preoperative anemia severity (no-anemia, mild anemia, moderate anemia, severe anemia) for postoperative open-heart adult patients (Tables 3.1 and 3.2). Significance was established at $p < .05$. A complete list of the 23 continuous variables evaluated can be found in Appendix A. Homogeneity of variances was assessed by Levene's test of homogeneity of variances; *Welch* robust test for equality of means are reported for those ANOVA results that do not meet the homogeneity of variance assumption. There was a statistically significant difference between preoperative anemia severity based on age ($p < .001$), BMI ($p < .001$), hemoglobin ($p < .001$), preop creatinine ($p < .001$), preop albumin ($p < .001$), preop A1c ($p = .001$), Hemo Data-EF ($p = .004$), intraop packed red blood cells ($p < .001$), intraop platelets ($p = .003$), postop creatinine ($p < .001$), postop hemoglobin ($p < .001$), initial ICU hours ($p < .001$), total OR hours ($p = .006$), admission to discharge LOS (days, $p < .001$), surgery to discharge LOS (days, $p = .006$), and total ICU hours ($p < .001$).

Pre-operative hemoglobin levels were significantly different for patients in terms of their anemia levels (*Welch's* $F[3, 34] = 179.54$, $p < .001$). Pre-operative hemoglobin levels decreased from the no anemia ($M = 14.40$, $SD = 0.99$), mild anemia ($M = 12.05$, $SD = 0.58$), moderate anemia ($M = 9.80$, $SD = 0.81$), and the severe anemia ($M = 7.26$, $SD = 1.07$) groups. Games-Howell post-hoc analysis revealed the decrease in pre-operative hemoglobin levels from the no anemia to the mild anemia groups (2.22, 95% CI 2.22 to 2.46, $p < .001$), from the mild to the moderate anemia groups (2.26, 95% CI 1.29 to 2.42, $p < .001$), and from the moderate to the severe anemia groups (2.54, 95% CI 1.29 to 3.79, $p = .001$) were statistically significant.

Table 3.2

*Clinical Characteristics of Study Population by Severity of Preoperative Anemia (*N *= 1,353)*

			Preoperative Anemia Severity[a]									
	Total		No Anemia		Mild		Moderate		Severe			
Characteristic	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	χ^2	***p***
Diabetes											58.82	< .001
Yes	713	52.7	292	45.6	212	33.1	130	20.3	6	0.9		
No	640	47.3	470	65.9	161	22.6	80	11.2	2	0.3		
Dyslipidemia											9.01	.024
Yes	1164	86.0	651	55.9	335	28.8	172	14.8	6	0.5		
No	189	14.0	111	58.7	38	20.1	38	20.1	2	1.1		
Hypertension											23.48	< .001
Yes	1177	87.1	637	54.1	347	29.5	187	15.9	6	0.5		
No	175	12.9	125	71.4	26	14.9	22	12.6	2	1.1		
Prior Myocardial Infarction											15.09	.001
Yes	553	40.9	279	50.5	166	30.0	103	18.6	5	0.9		
No	800	59.1	483	60.4	207	25.9	107	13.4	3	0.4		
Cardiac Presentation Symptoms											35.50	.004[b]
Angina equivalent	41	3.0	24	58.5	10	24.4	7	17.1	0	0.0		
No symptoms	90	6.7	50	55.6	24	26.7	15	16.7	1	1.1		
Non-ST elevation MI	280	20.7	134	47.9	81	28.9	63	22.5	2	0.7		
ST elevation MI	39	2.9	19	48.7	12	30.8	8	20.5	0	0.0		
Stable angina	73	5.4	47	64.4	23	31.5	3	4.1	0	0.0		
Unstable angina	381	28.2	224	58.8	115	30.2	40	10.5	2	0.5		
Other	448	33.1	264	58.9	107	23.9	74	16.5	3	0.7		
ADP Inhibitors Within 5 Days											8.36	.034
Yes	63	4.7	26	41.3	21	33.3	15	23.8	1	1.6		
No	1289	95.3	736	57.1	351	27.2	195	15.1	7	0.5		

Table 3.2 (continued)

	Total		Preoperative Anemia Severity[a]									
			No Anemia		Mild		Moderate		Severe			
Characteristic	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	χ^2	***p***
Anticoagulants Within 48 Hours											32.57	< .001
Yes	527	39.0	255	48.4	154	29.2	112	21.3	6	1.1		
No	826	61.0	507	61.4	219	26.5	98	11.9	2	0.2		
Surgery Status											59.64	< .001
Elective	477	35.3	326	68.3	115	24.1	36	7.5	0	0.0		
Urgent or emergent reason	876	64.7	436	49.8	258	29.5	174	19.1	8	0.9		
Urgent Surgery Reason											76.45	< .001[b]
AMI; ongoing ischemia; USA; worsening CP; rest angina; syncope	357	40.8	181	50.7	98	27.5	76	21.3	2	0.6		
Anatomy, intra cardiac mass or thrombus, valve dysfunction	130	14.9	77	59.2	32	24.6	19	14.6	2	1.5		
Angiographic accident, diagnostic/ interventional procedure complication; PCI incomplete without clinical deterioration	1	0.1	1	100.0	0	0.0	0	0.0	0	0.0		
Aortic aneurysm, aortic dissection	12	1.4	5	41.7	6	50.0	1	8.3	0	0.0		
CHF, pulmonary edema	109	12.5	45	41.3	38	34.9	25	22.9	1	0.9		
Trauma, other	234	26.8	125	53.4	78	33.3	30	12.8	1	0.4		
Endocarditis	31	3.5	2	6.5	5	16.1	22	71.0	2	6.5		
Intraop Blood Products											162.44	< .001
Yes	673	50.0	281	41.8	211	31.4	174	25.9	7	1.0		
No	672	50.0	476	70.8	160	23.8	35	5.2	1	0.1		
Intraop Epsilon Aminocaproic Acid											16.66	.001
Yes	1041	76.9	614	59.0	279	26.8	142	13.6	6	0.6		
No	312	23.1	148	47.4	94	30.1	68	21.8	2	0.6		

Table 3.2 (continued)

			Preoperative Anemia Severity[a]									
	Total		No Anemia		Mild		Moderate		Severe			
Characteristic	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	χ^2	***p***
Intraop Tranexamic Acid											9.27	.022
Yes	213	15.7	104	48.8	61	28.6	47	22.1	1	0.5		
No	1140	84.3	658	57.7	312	27.4	163	14.3	7	0.6		
Cardiopulmonary Bypass											14.22	.024
No	214	17.8	116	48.1	81	33.6	43	17.8	1	0.4		
Full	1107	81.8	645	58.3	290	26.2	165	14.9	7	0.6		
Combination	5	0.4	1	20.0	2	40.0	2	40.0	0	0.0		
Valve Procedure: Mitral											7.64	.022
Repair, reconstruction	139	63.2	85	61.2	28	20.1	26	18.7	0	0.0		
Replacement	81	36.8	34	42.0	25	30.9	22	27.2	0	0.0		
Readmission into ICU											9.13	.026
Yes	41	3.0	17	41.5	11	26.8	12	29.3	1	2.4		
No	1312	97.0	745	56.8	362	27.6	198	15.1	7	0.5		
Postop Sternal-Superficial Infection											9.32	.007
Yes, within 30 days of procedure	11	28.9	9	81.8	1	9.1	1	9.1	0	0.0		
No	27	71.1	7	25.9	13	48.1	7	25.9	0	0.0		
Postop Renal Impairment											15.40	.001
Yes	41	6.3	11	26.8	16	39.0	13	31.7	1	2.4		
No	615	93.8	364	56.3	162	26.3	101	16.4	6	1.0		
Postop Dialysis After Discharge											7.60	.041
Yes	9	45.0	0	0.0	3	33.3	5	55.6	1	11.1		
No	11	55.0	6	54.5	2	18.2	3	27.3	0	0.0		

Table 3.2 (continued)

	Total		Preoperative Anemia Severity									
			No Anemia		Mild		Moderate		Severe			
Characteristic	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	χ^2	***p***
Postop Other Cardiac Arrest											13.0	.004
Yes	25	3.8	357	54.4	178	27.1	114	17.4	7	1.1		
No	631	96.2	350	55.5	168	26.6	108	17.1	5	0.8		
Postop Other A Fib											24.97	< .001
Yes	443	67.5	265	59.8	115	26.0	62	14.0	1	0.2		
No	213	32.5	92	43.2	63	29.6	52	24.4	6	2.8		
Discharge Location											96.61	< .001[b]
Extended care, transitional care unit	224	16.6	70	31.3	88	39.3	64	28.6	2	0.9		
Home	1108	82.0	685	61.8	277	25.0	140	12.6	6	0.5		
Nursing home	9	0.7	2	22.2	4	44.4	3	33.3	0	0.0		
Other acute care hospital	9	0.7	3	33.3	4	44.4	2	22.2	0	0.0		
Left against medical advice	1	0.1	0	0.0	0	0.0	1	100.0	0	0.0		
Other	1	0.1	1	100.0	0	0.0	0	0.0	0	0.0		
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***F***	***p***
Preop Hemoglobin	13.00	1.97	14.40	0.99	12.05	0.58	9.80	0.81	7.26	1.07	1788.54	< .001[c]
Preop Creatinine	1.23	1.24	0.97	0.39	1.16	0.97	2.22	2.44	2.73	3.62	21.39	< .001[c]
Preop Total Albumin	3.83	0.52	4.00	0.44	3.77	0.46	3.37	0.53	3.17	0.98	80.88	< .001[c]
Preop A1c Level	6.48	1.54	6.32	1.40	6.69	1.67	6.71	1.67	7.15	2.93	6.02	.003[c]
Hemo Data EF	54.57	13.37	55.67	12.81	54.26	13.59	51.31	14.52	50.85	9.30	5.38	.004[c]
Intraop Packed Red Blood Cells	2.20	2.35	1.34	1.79	2.42	2.19	3.19	2.71	5.86	2.67	33.50	< .001
Intraop Platelet	1.59	2.05	1.93	1.77	1.41	2.22	1.28	2.19	1.14	1.68	4.65	.003
Postop Creatinine	1.57	1.50	1.19	0.67	1.58	1.32	2.86	2.62	3.41	4.11	35.54	< .001[c]
Postop Hemoglobin	9.91	1.39	10.32	1.39	9.51	1.19	9.12	1.15	8.1	0.00	8.52	< .001
Initial ICU Hours	80.54	123.44	66.46	75.66	88.39	163.81	110.55	137.01	270.16	173.37	8.22	< .001[c]

Table 3.2 (continued)

	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*
Total OR Time	6.22	1.70	6.10	1.80	6.29	1.53	6.53	1.60	6.71	1.50	4.14	.006
Admission to Discharge LOS (days)	14.93	14.21	12.41	10.64	15.07	10.88	21.47	11.45	34.14	27.53	9.16	< .001[c]
Surgery to Discharge LOS (days)	11.43	10.30	10.16	9.69	11.78	9.26	14.05	11.51	25.71	24.73	5.08	.006[c]
Total ICU Hours	86.27	139.83	70.89	96.50	93.49	173.58	122.06	165.38	276.80	487.30	7.45	.001[c]

Note. BMI = Body Mass Index; EF = Ejection Fraction; ICU = Intensive Care Unit; LOS = Length of Stay; *M* = Mean; *SD* = Standard Deviation; OR = Operation Room; χ^2 = Fisher's Exact Test unless otherwise specified. [a]Preoperative Anemia Severity: No-anemia (hb ≥ 13 g/dL), mild anemia (hb 10.1-12.9 g/dL), moderate anemia (hb 8-10g/dL), and severe anemia (hb < 8g/dL). [b]Monte Carlo Sig. (2-sided). [c]Welch Sig. (2-sided).

30-Day Hospital Readmission

Bivariate analyses (chi-square and Fisher's exact tests for association) were conducted to evaluate the relationship between categorical variables and 30-day hospital readmission for postoperative open-heart adult patients; independent-samples t-tests were conducted between continuous variables and 30-day hospital readmission (Tables 3.3 and 3.4). A complete list of the 60 categorical and 23 continuous variables evaluated can be found in Appendix A. The level of significance for all bivariate analyses was set to $p <$ .05.

There was a statistically significant difference between 30-day hospital readmission and: hospital name (Fisher's $\chi^2(2) = 25.02$, $p < .001$, *Cramer's V* = .136; small effect); admission source (Fisher's $\chi^2(3) = 27.92$, $p < .001$, *Cramer's V* = .145; small effect); diabetes (Fisher's $\chi^2(1) = 6.33$, $p = .012$, *Phi* = .069; small effect); hypertension (Fisher's $\chi^2(1) = 5.94$, $p = .016$, *Phi* = .067; small effect); tobacco use (Fisher's $\chi^2(1) = 13.71$, $p < .001$, *Phi* = .102; small effect); preop anemia severity (Fisher's $\chi^2(3) = 21.34$, $p < .001$, *Cramer's V* = .130; small effect); preop anemia yes/no (Fisher's $\chi^2(1) = 15.13$, $p < .001$, *Phi* = .107; small effect); cardiac presentation symptoms ($\chi^2(6) = 13.20$, $p = .037$, *Cramer's V* = .102; small effect), valve procedure yes/no (Fisher's $\chi^2(1) = 10.35$, $p = .001$, *Phi* = -.089; small effect), and postop Intra-Aortic Balloon Pump (Fisher's $\chi^2(1) = 16.37$, $p < .001$, *Phi* = .112; small effect; Tables 3.1 and 3.2).

Independent samples t-tests indicated patients who were readmitted within 30 days of hospital discharge had lower preop hemoglobin levels (*M* = 12.32, *SD* = 2.07) than those who were not readmitted (*M* = 13.09, *SD* = 1.94), a statistically significant difference of 0.77 (95% CI, 0.46 to 1.08, $t[1313] = 4.845$, $p < .001$); patients readmitted also had lower preop total albumin levels ($M = 3.67$, $SD = 0.56$) than those who were not readmitted ($M = 3.86$, $SD = 0.51$), a statistically significant difference of 0.19 (95% CI, 0.10 to 0.27, $t[1190] = 4.362$, $p < .001$). Furthermore, patients who were readmitted within 30 days of hospital discharge had higher preop creatinine levels ($M = 1.53$, $SD = 1.66$) than those who were not readmitted ($M = 1.15$, $SD = 1.25$), a statistically significant difference of 0.38 (95% CI, -0.69.46 to -0.07, $t[328] = -2.439$, $p = .015$). Patients readmitted also had higher preop A1c levels ($M = 6.86$, $SD = 1.91$) than those who were not readmitted ($M = 6.42$, $SD = 1.40$), a statistically significant difference of 0.44 (95% CI, -0.80 to -0.08, $t[302] = -2.394$, $p = .017$), and patients readmitted had higher postop creatinine levels ($M = 2.08$, $SD = 1.96$) than those who were not readmitted ($M = 1.36$, $SD = 1.00$), a statistically significant difference of -0.73 (95% CI, -1.05 to -0.40, $t[263] = -4.407$, $p > .001$).

Independent samples t-tests also revealed that patients who were readmitted within 30 days of hospital discharge stayed longer at the ICU initially and overall, had longer operation times, and had longer stays at the hospital (admission to discharge) than those who were not readmitted (Table 3.4).

Table 3.3

Sociodemographic Characteristics of Study Population by 30-Day Hospital Readmission (N = 1,353)

	Total		30-Day Hospital Readmission[a] Yes		30-Day Hospital Readmission[a] No			
Characteristic	***n***	**%**	***n***	**%**	***n***	**%**	χ^2	***p***
Gender							0.28	.593
Female	389	28.8	54	14.2	325	85.8		
Male	946	71.2	123	13.1	813	86.9		
Race							2.35	.672
White, non-Hispanic	573	44.1	78	13.9	483	86.1		
Hispanic, Latino	358	27.6	45	12.9	304	87.1		
Black, African American	32	2.5	6	19.4	25	80.6		
Asian, Pacific Islander	146	11.2	16	11.2	127	88.8		
Other	189	14.6	27	15.3	150	84.7		
Hospital								
Hospital A	334	24.7	53	16.3	273	83.7	25.02	<.001
Hospital B	430	31.8	75	18.6	329	81.4		
Hospital C	589	43.5	49	8.4	536	91.6		
Admission Source							27.18	< .001
Elective admission	663	49.0	56	8.6	596	91.4		
Emergency department	597	44.1	106	18.5	466	81.5		
Transfer from hospital or acute care facility, or other admission source	93	6.9	15	16.5	76	83.5		
	M	***SD***	***M***	***SD***	***M***	***SD***	***t***	***p***
Age	64.16	11.00	65.31	11.03	64.05	10.89	- 1.43	.154
BMI	28.86	5.83	28.61	6.78	28.17	5.80	- 0.66	.512

Note. BMI = Body Mass Index; *M* = Mean; *SD* = Standard Deviation; χ^2 = Fisher's Exact Test unless otherwise specified. [a]30-Day Hospital Readmission = Any hospital readmission within the first 30-days after hospital discharge. [b]Welch Sig. (2-sided).

Table 3.4

*Clinical Characteristics of Study Population by 30-Day Hospital Readmission (*N *= 1,353)*

			30-Day Hospital Readmission[a]					
	Total		Yes		No			
Characteristic	***n***	**%**	***n***	**%**	***n***	**%**	χ^2	***p***
Diabetes							6.33	.012
Yes	640	47.3	99	55.9	521	45.8		
No	713	52.7	78	44.1	617	54.2		
Hypertension							5.94	.007
Yes	1177	87.1	163	92.6	978	85.9		
No	175	12.9	13	7.4	160	14.1		
Tobacco Use							13.71	< .001
Yes	654	48.3	108	61.0	521	46.1		
No	692	51.1	69	39.0	610	53.9		
Preoperative Anemia							21.34	< .001
No-anemia	762	56.3	76	42.9	666	58.5		
Mild anemia	373	27.6	53	29.9	307	27.0		
Moderate anemia	210	15.5	46	26.0	159	14.0		
Severe anemia	8	0.6	2	1.1	6	0.5		
Preoperative Anemia							15.13	< .001
No-anemia	762	56.3	76	42.9	666	58.5		
Anemia	591	43.7	101	57.1	472	41.5		
Cardiac presentation symptoms							13.20	.037[b]
Angina equivalent	41	3.0	6	3.4	31	2.7		
No symptoms	90	6.7	11	6.8	77	6.2		
Non-ST elevation MI	280	20.7	53	29.9	217	19.1		
ST elevation MI	39	2.9	7	2.6	29	4.0		
Stable angina	73	5.4	8	5.5	63	4.5		
Unstable angina	381	28.2	43	24.3	328	28.8		
Other	448	33.1	49	27.7	392	34.5		

Table 3.4 (continued)

Characteristic	Total		30-Day Hospital Readmission[a] Yes		No			
	n	%	*n*	%	*n*	%	χ^2	*p*
Urgent Surgery Reason							9.83	.120
AMI; ongoing ischemia; USA; worsening CP; rest angina; syncope	357	40.8	64	46.4	280	39.8		
Anatomy, intra cardiac mass or thrombus, valve dysfunction	130	14.9	25	18.1	99	14.1		
Angiographic accident, diagnostic/interventional procedure complication; PCI incomplete without clinical deterioration	1	0.1	1	0.7	0	0.0		
Aortic aneurysm, aortic dissection	12	1.4	1	0.7	11	1.6		
CHF, pulmonary edema	109	12.5	14	10.1	91	12.9		
Trauma, other	234	26.8	28	20.3	197	28.0		
Endocarditis	31	3.5	5	3.6	26	3.7		
Valve							10.35	.001
Yes	554	40.9	54	30.5	493	43.3		
No	799	59.1	645	56.7	123	69.5		
Postop Intra-Aortic Balloon Pump							16.37	< .001
Yes	138	10.2	33	18.6	100	8.8		
No	1215	89.8	144	81.4	1038	91.2		
Postop Renal Impairment							1.71	.252
Yes	41	6.3	9	9.0	30	5.6		
No	615	93.8	91	91.0	507	94.4		

Table 3.4 (continued)

	M	*SD*	*M*	*SD*	*M*	*SD*	*t*	*p*
Preop Hemoglobin	13.00	1.97	12.32	2.07	13.09	1.94	4.85	< .001
Preop Creatinine	1.23	1.24	1.53	1.66	1.15	1.25	- 2.44	.015
Preop total Albumin	3.83	0.52	3.67	0.56	3.86	0.51	4.36	< .000
Preop A1c	6.48	1.54	6.86	1.91	6.42	1.40	- 2.39	.017
Hemo Data EF	54.57	13.37	50.74	14.64	55.44	12.45	3.19	.002

			30-Day Hospital Readmission[a]					
	Total		**Yes**		**No**			
Characteristic	*M*	*SD*	*M*	*SD*	*M*	*SD*	*t*	*p*
Postop Creatinine	1.57	1.50	2.08	1.96	1.36	1.00	- 4.41	< .001
Initial ICU Hours	80.54	123.43	98.08	121.30	78.11	125.08	-1.98	.048
Total OR Time	6.22	1.70	6.50	1.52	6.18	1.74	-2.35	.019
Admission to Discharge LOS (days)	14.93	14.21	17.78	16.05	14.36	13.89	-2.33	.020
Total ICU Hours	2722.00	139.83	113.90	163.49	75.98	122.72	- 2.47	.014

Note. BMI = Body Mass Index; *M* = Mean; *SD* = Standard Deviation; χ^2 = Fisher's Exact Test unless otherwise specified. [a]30-Day Hospital Readmission = Any hospital readmission within the first 30-days after hospital discharge. [b]Monte Carlo.

Multiple Predictors of 30-Day Hospital Readmission

A binomial logistic regression analysis was conducted to examine the effects of sociodemographic characteristics (gender, hospital admission source), preoperative risk factors (diabetes, hypertension, tobacco use, preoperative anemia, last creatinine, total albumin, and Ac1 level, cardiac presentation at admission, reason for surgery), intraoperative factors (surgery type), and postoperative factors (peak glucose level, postop IABP, renal impairment) on the likelihood that adult postoperative open-heart patients are readmitted to the hospital within 30 days of discharge. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. All continuous independent variables were found to be linearly related to the logit of the dependent variable. The logistic regression model was also statistically significant ($\chi^2[27] = 68.61$, $p < .001$). The model explained between 17.9% (Cox & Snell R^2) and 28.1% (Nagelkerke R^2) of the variance in hospital readmission and correctly classified 96% of cases. Sensitivity was 25.4%, specificity was 96%, positive predictive value was 62.07%, and negative predictive value was 83.4%. Seven of the 15 predictor variables were statistically significant: (a) hospital admission source, (b) hypertension, (c) tobacco use, (d) preoperative anemia, (e) cardiac presentation at admission, (f) reason for urgent or emergent surgery, and (g) IABP. When compared to patients with an elective admission to the hospital, those admitted to the hospital through the emergency department were 7.35 times (95% *CI* 2.17, 24.9) more likely to be readmitted to the hospital in the first 30 days after hospital discharge; those transferred from another hospital, acute care facility, or any other facility were 7.96 times (95% *CI* 1.88, 33.66) more likely to be readmitted. Patients with hypertension were 9.5

times (95% *CI* 1.77, 51) more likely to be readmitted. Patients who used tobacco products were 2.71 times (95% *CI* 1.45, 5.08) more likely to be readmitted. When compared to patients with no anemia, only patients with severe anemia were 14.29 times (95% *CI* 1.22, 167.9) more likely to be readmitted. When compared to patients whose cardiac presentation at admission was angina equivalent, those with non-ST elevation myocardial infarction (NSTEMI) were .16 times (95% *CI* .03, .98) more likely to be readmitted, and those with ST elevation MI (STEMI) were .11 times (95% *CI* .01, .94) more likely to be readmitted. When compared to patients with an urgent or emergent surgery reason of AMI, ongoing ischemia, USA, worsening CP, rest angina, or syncope, those with an urgent or emergent surgery reason identified as anatomy, intra cardiac mass or thrombus, or a valve dysfunction were 4.61 times (95% *CI* 1.28, 16.61) more likely to be readmitted. Finally, patients who had an IABP were 3.12 times (95% *CI* 1.53, 6.38) more likely to be readmitted.

Discussion

Main Findings

The purpose of this multi-center cross-sectional study was to retrospectively examine the relationship between preoperative anemia (hb < 13g/dL) and 30-day hospital readmission among adult postoperative open-heart patients. To accomplish the objective of this study, the two specific aims of this research were to estimate the prevalence of preoperative anemia among adults seeking urgent or elective open-heart surgery and to examine the relationship between preoperative anemia, social determinants of health and 30-day hospital readmission rates among postoperative open-heart adult patients.

In this study, significant patient characteristics and their association with preoperative anemia and 30-day hospital readmission were identified. Data from 1,353 cases from August 2014 through July 2018 across three acute care community hospitals in southern California were extracted and examined. Of those, 177 (13%) experienced a 30-day readmission.

Prevalence of anemia. In this study, the prevalence of adult patients with preoperative anemia was 44%, which is consistent with previous reports examining anemia in the adult cardiac surgery population (Dai et al., 2018; Hubert et al., 2019; Karkouti et al., 2008; Kulier et al., 2007; Musallam et al., 2011; Nuis et al., 2013). Among those with anemia, 28% were classified as mild, 15% as moderate, and 1% as severe. This distribution of preoperative anemia is similar to findings reported in the literature (Nuis et al., 2013).

Preoperative anemia and sociodemographics. Cases of preoperative anemia were more prevalent at Hospitals A and B, correlating with cases of preoperative anemia by region. Patients from Hospital A typically reside within the "south" region of southern California, while Hospital B's patients are located in the "east" and "outside county east."

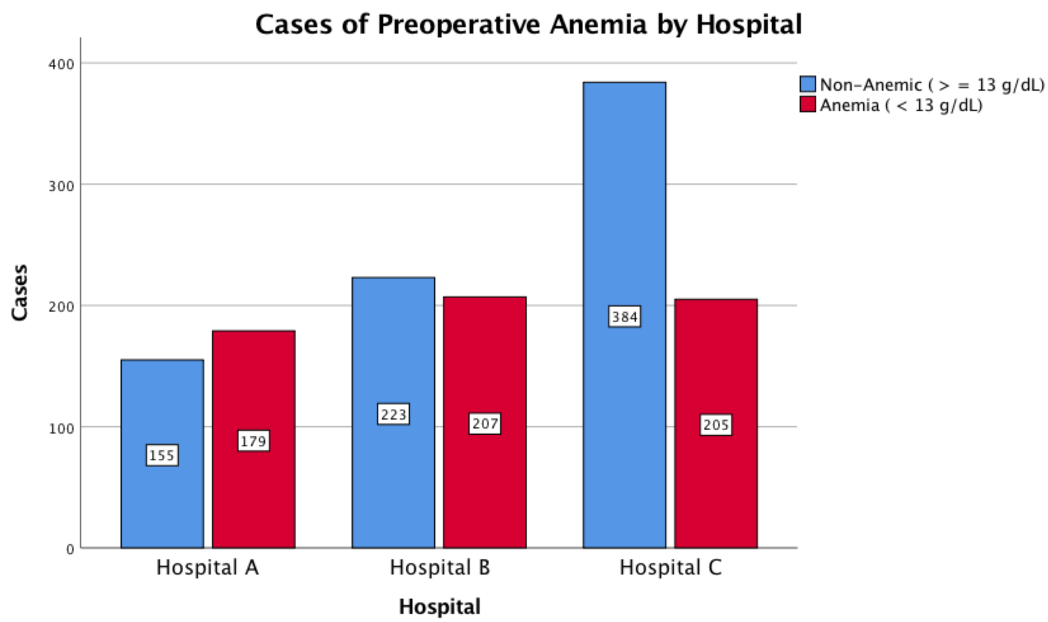

Figure 3.2. Cases of preoperative anemia by hospital facility.

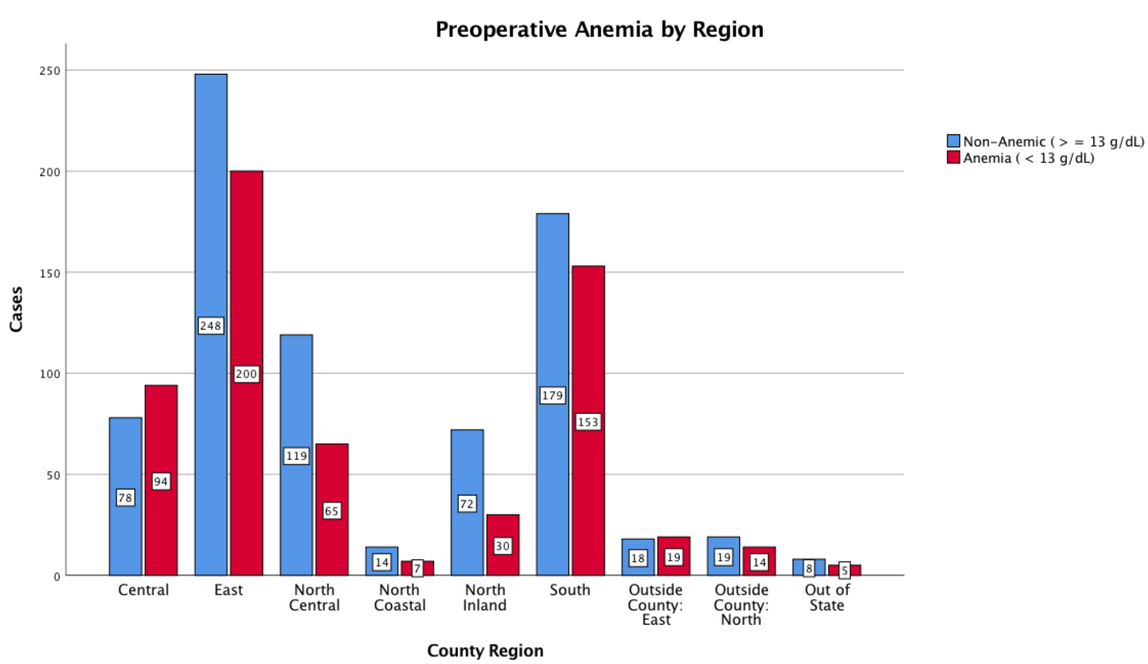

Figure 3.3. Cases of preoperative anemia by region.

Study findings indicated the prevalence of preoperative anemia was higher in Hispanic, Black, and Asian/Pacific Islander patient populations. Burton et al. (2019) concluded preoperative anemia may not only be associated with racial differences and a higher comorbidity burden but may also increase the likelihood of postoperative morbidity and mortality. This study did not examine the relationship between race and morbidity and mortality directly.

Three quarters of the cases in this study identified Medicare (76%) as the primary payor. Considering Medicare is available to persons 65 years and older and the majority of adult patients undergoing open-heart surgery are also 65 and older, it is no surprise Medicare is the primary payor (Karkouti et al., 20018; Nuis et al., 2013).

Gender plays a key role in preoperative anemia and postoperative morbidity and mortality outcomes. While there were more male than female cases in this study, the female patient population had a higher incidence of preoperative anemia. Raju, Eisenberg, Montbriand, and Roche-Nagle (2018) noted an association between preoperative hemoglobin levels of both genders and in-hospital mortality, adverse cardiac events, and postoperative complications, with males having a higher risk overall.

Preoperative anemia and surgical timing. Little is known about the influence of surgical admitting source and clinical outcomes among patients undergoing open-heart surgery. In this study, patients who admitted to the hospital for surgery electively had a lower preoperative anemia rate than patients admitted through the emergency department or as an outside transfer from another facility. Additionally, patients who required open-heart surgery urgently had a higher prevalence of preoperative anemia than their electively scheduled counterparts.

Preoperative anemia and transfusion. Patients with preoperative anemia are at a higher risk for red blood cell transfusion both perioperatively and postoperatively. Red blood cell transfusion itself is associated with adverse clinical outcomes (Hubert et al., 2019; Mirzaei, Hershberger & DeVon, 2019). This is consistent with the findings of this study, which showed an association exists between preoperative anemia and red blood cell transfusion both perioperatively and postoperatively.

Guidelines for blood product use in cardiac surgery patients have been established for well over a decade in the United States. Ferraris et al. (2007) identified six variables to serve as critical indicators of risk: (a) advanced age, (b) low preoperative red blood cell volume (preoperative anemia or small body size), (c) preoperative antiplatelet or antithrombotic drugs, (d) preoperative or complex procedures, (e) emergency operations, and (f) noncardiac patient comorbidities. In this study, patients identified as anemic preoperatively had a much higher probability of receiving blood product transfusion perioperatively. Only 37% of patients with no anemia received a perioperative transfusion, compared to 57% of patients with mild anemia, 83% of patients with moderate anemia, and 89% of severely anemic patients (Hung, Besser, Sharples, Nair, & Klein, 2011; Karkouti et al., 2008; Von Heymann et al., 2016). Many of the patients who received blood product transfusions in this study met several if not all six criteria.

Implementation of risk prediction instruments that contain evidenced-based transfusion risk criteria is critical for improved patient outcomes. Blood management programs now exist worldwide and are aimed at helping organizations and multidisciplinary clinicians examine their current practices and opportunities for improvement in their use of blood products (Mueller et al., 2019). Implementation of a blood management program has been shown to reduce adverse patient outcomes and provide organizations considerable cost savings (Gross, Seifert, Hofmann, & Spahn, 2015; Leahy et al., 2017; Meybohm et al., 2016; Scolletta et al., 2019). Reviewing patients' risk factors for blood product transfusion, including anemia, and providing treatment preoperatively is key. Jin el al. (2019) examined the benefits of intravenous iron administration on preoperative anemic patients, and findings showed a reduction in blood product transfusions and a correlation with decreased length of stay. Local policies and procedures should include such practices in attempt to improve patient outcomes.

Preoperative anemia, hospital discharge, and readmission. Upon examination of the results, the investigator identified a higher percentage of patients with preoperative anemia being discharged to an extended care or transitional unit, nursing home, or other acute care facility. There is a dearth of literature specifically examining the association between preoperative anemia and discharge locations; nonetheless, it can be assumed patients discharging to a facility other than home are likely fairly ill, requiring extended care from licensed professionals.

Cho et al. (2019) suggest an association exists between patients with severe anemia (hb < 8g/dL) at discharge and 30-day hospital readmission. The current study's findings also found patients identified as having anemia preoperatively were more likely to incur a 30-day readmission. Of patients who were readmitted to the hospital within 30 days, those identified as having preoperative anemia were more likely to return to the hospital for an anticoagulation problem, chest pain, congestive heart failure, deep vein thrombosis (DVT), infection of the conduit harvest site, pericardial effusion, respiratory complications, sepsis, endocarditis, and other reasons, both surgical and non-surgical related. To date, the investigator has not found literature examining the association between preoperative anemia and the reasons specified for 30-day hospital readmission. This information provides valuable insight into the potential post-discharge problems preoperative anemic patients may face and begs the question, "Could these complications be avoided if anemia were treated either during the hospitalization or post-discharge, if not preoperatively?"

Strengths and Limitations

A cross-sectional study design was particularly suitable for this study as the research question sought to understand the prevalence of preoperative anemia in the adult cardiac surgery population. The study design allowed the investigator to examine multiple risk factors, including sociodemographic, and assess more than one outcome. A G-Power analysis was run using 90% confidence and two-tailed, .05 significance values. With over 80 variables included, the estimated number of cases needed for this study was 1,288. Over a four-year period, August 2014 through July 2018, the study yielded an adequate sample size of 1,353 cases.

This study examined several demographic, comorbidity, surgical, and transfusion criteria; nonetheless an important limitation to this study is the lack of adjustment for perioperative and postoperative surgical bleeding. Tauriainen, Koski-Vähälä, Kinnunen, and Biancari (2017) found adverse events were no longer associated with preoperative anemia when adjusted for key baseline criterion, procedural components, surgical bleeding, and blood product transfusion.

The STS refer to Data Managers as the primary source of data input. Data managers review training modules and have access to several online resources to help manage the data input process. However, the accuracy of the collected data may be at risk. To the best of the investigator's knowledge, no interrater reliability testing has been performed. The investigator could not validate the accuracy of the data set values.

Conclusion

Patients with preoperative anemia are more likely to be readmitted to the hospital within 30 days of discharge than those without anemia. Health care providers have the opportunity to promote positive outcomes through assessment, treatment, and evaluation of anemia preoperatively. Routine preoperative blood work should be closely examined for the presence of anemia, followed by treatment if indicated. Further research is needed to evaluate the effects of various preoperative anemia treatments and patient outcomes.

Appendix A. *Study Variables Evaluated in the Analyses*

	Categorical Variables
1.	Patient gender
2.	Patient ZIP code
3.	Race w/Hispanic as a category
4.	Hospital Name
5.	Primary Payor
6.	Primary Payor Medicare Fee For Service
7.	Admission source
8.	RF: Diabetes
9.	RF: Dyslipidemia
10.	RF: Hypertension
11.	RF: Tobacco Use
12.	RF: Prior Cardiovascular accident
13.	RF: Preop Anemia
14.	RF: Prior cardiac intervention
15.	RF: Prior MI
16.	RF: Cardiac presentation symptoms at admission
17.	Meds: ADP Inhibitors w/in 5 days
18.	Meds: Aspirin w/in 5 days
19.	Meds: Glycoprotein IIb/IIIa Inhibitor w/in 24 hours
20.	Meds: Anticoagulants w/in 48 hours
21.	Meds: Warfarin (Coumadin) w/in 5 days
22.	Meds: Factor Xa Inhibitors w/in 5 days
23.	Meds: Novel Oral Anticoagulant w/in 5 days
24.	Meds: Thrombin Inhibitors w/in 5 days
25.	Meds: Thrombolytics w/in 48 hours
26.	Surgery status
27.	Urgent or emergent reason
28.	Intraop Blood Products
29.	Intraop Blood Products: RBC Units
30.	Intraop Blood Products: FFP Units
31.	Intraop Blood Products: Platelet Units
32.	Intraop Blood Products: Cryo Units
33.	Intraop Antifibrinolytic Meds: Epsilon Aminocaproic Acid
34.	Intraop Antifibrinolytic Med: Tranexamic Acid
35.	Coronary Artery Bypass (CAB)
36.	Cardiopulmonary Bypass (CPB) utilization
37.	VS: Valve
38.	VS: Aortic Valve Procedure
39.	VS: Mitral Valve Procedure
40.	Blood Products
41.	Blood Products: RBC Units
42.	Blood Products: FFP Units

Appendix A (continued)

	Categorical Variables
43.	Blood Products: Platelet Units
44.	Blood Products: Cryo Units
45.	Initial ICU Hours
46.	Readmission to ICU
47.	Postop Intra-Aortic Balloon Pump (IABP)
48.	Postop Sternal-Superficial Wound Infection
49.	Postop Deep Sternal Infection / Mediastinitis
50.	Postop Conduit Harvest
51.	Postop Wound Intervention / Procedure
52.	Postop Renal-19
53.	Postop Renal-Dialysis Required
54.	Postop Dialysis Required After Discharge
55.	Postop Other-Card Arrest
56.	Postop Other-A Fib
57.	Mortality 30d Status
58.	Discharge Location
59.	Readmission (30d from hosp d/c)
60.	Readmission reason (28cat)
	Continuous Variables
61.	Patient age
62.	RF: Patient BMI (kg/m2)
63.	RF: Hemoglobin
64.	RF: Last Creat Level
65.	RF: Total Albumin
66.	RF: Last A1c Level
67.	Hemo Data-EF
68.	Intraop Blood Products: RBC Units
69.	Intraop Blood Products: FFP Units
70.	Intraop Blood Products: Platelet Units
71.	Intraop Blood Products: Cryo Units
72.	Postoperative Peak Glucose
73.	Postoperative Creatinine Level
74.	Postoperative Hemoglobin
75.	Blood Products: RBC Units
76.	Blood Products: FFP Units
77.	Blood Products: Platelet Units
78.	Blood Products: Cryo Units
79.	Initial ICU Hours
80.	Total OR Time (Hours)
81.	Admission to Discharge LOS (Days)
82.	Surgery to Discharge LOS (Days)
83.	Total ICU Hours

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CHAPTER IV

MANUSCRIPT #3

Coronary Artery Bypass Grafting and the Hospital Readmission Reduction Program

Lindsey J. Ryan

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Abstract

Aims: The aims of this policy analysis are to explain the development and impact of the Hospital Readmission Reduction Program and to discuss the political, social, and economic implications of coronary artery bypass grafting as a newly targeted condition within the Hospital Readmission Reduction Program.

Background: Open-heart surgery yields a very high index cost, more than $149,000, and has an associated length of stay averaging 9.2 days. Compared to all condition readmissions, patients who had CABG procedures had the second highest average Medicare payment per readmission at $8,136, an annual cost of $151 million. Implementation of the U.S. Patient Protection and Affordable Care Act (ACA) in 2010 provided government agencies with structures and processes to hold hospitals accountable for improving the quality of care delivered, while reducing health care costs. Safety net hospitals may be at risk for disproportionate fines due to social factors beyond their control.

Design: Policy analysis.

Data Sources: Peer reviewed literature was gathered using PubMed and CINAHL databases. Additional information was retrieved from AARP, AHRQ, CMS, Commonwealth Fund, DHHS, HRSA, Kaiser Family Foundation, and the Library of Congress.

Methods: The paper is presented in accordance with Bardach and Patashnik's eight-step policy analysis procedure.

Results: Safety-net hospitals (SNH) that care for a much higher rate of disadvantaged and uninsured patient populations have struggled to develop solutions that keep patients

healthy and out of the hospital. Unsurprisingly, these SNHs are proportionally receiving too many higher penalties (44%) compared to non-SNHs (30%), stimulating the need for re-evaluation of current penalty programs and formulas. Through examination of the evidence addressing the associations between insurance and 30-day hospital readmissions following a CABG procedure, penalty programs may be adjusted to better capture sociodemographic differences.

Conclusions: Patients undergoing CABG procedures are faced with a higher than normal likelihood of experiencing a hospital readmission 30 days following discharge. One strategy to improve morbidity and reduce hospital readmissions among postoperative CABG patients is to first identify those who are potentially at high risk for poor outcomes. Nurses are well positioned to lead changes in these upstream issues, including surgical risk assessments and transitions in care across the continuum.

Keywords: Hospital Readmission Reduction Program, HRRP, Value-Based Purchasing, Coronary Artery Bypass Graft, CABG

Coronary Artery Bypass Grafting and the Hospital Readmission Reduction Program

In 2008, health care costs soared to $2.4 trillion annually, averaging $7,868 per capita, the highest in the world (Kaiser Family Foundation, 2008). Open-heart surgery alone yields a very high index cost of more than $149,000 and has an associated length of stay averaging 9.2 days (Mozaffarian et al., 2016). Compared to all condition readmissions, coronary artery bypass graft (CABG) patients had the second highest average Medicare payment per readmission at $8,136 per visit, an annual cost of $151 million (Medicare Payment Advisory Committee [MedPAC], 2007). The two aims of this analysis, which utilizes Bardach and Patashnik's (2016) eight-step policy analysis procedure, are to explain the development and impact of the Hospital Readmission Reduction Program (HRRP), and to discuss the political, social, and economic implications of CABG as a newly targeted condition within the HRRP.

Defining the Problem

Implementation of the U.S. Patient Protection and Affordable Care Act (ACA) in 2010 provided government agencies with structures and processes to hold hospitals accountable for improving the quality of care delivered and reducing health care costs. While tremendous improvements have been made in several areas of health care as a result of the ACA (e.g., increased access to care, decreased uninsured Americans, reduced readmission rates, and slowed growth of health care costs), disparities in quality care and outcomes persist (Adepoju, Preston, & Gonzales, 2015; Chen, Vargas-Bustamante, Mortensen & Ortega, 2016; French, Homer, Gumus, & Hickling, 2016; Martin, Hartman, Whittle, Catlin, & National Health Expenditure Accounts Team, 2014). Contributing factors tied to these disparate findings include socioeconomic status, quality of providers, uneven distribution of resources devoted to performance improvement efforts, and an overall sicker population (Lewis, Fraze, Fisher, Shortell, & Colla, 2017). The Department of Health and Human Services (DHHS; 2015) reported 62% of high-income hospitals paid $78 million in penalties, compared to 85% of low income hospitals that absorbed $117 million dollars in penalties (see Figures 4.1 and 4.2).

Low socioeconomic status is directly linked to increased morbidity and mortality; notably, individual costs associated with health care coverage and out-of-pocket expenses are leading barriers to consumption of health care services (Adepoju et al., 2015; Adler & Newman, 2002). Safety-net hospitals (SNH) that care for a much higher rate of disadvantaged and uninsured patient populations have struggled to develop solutions to keep patients healthy and out of the hospital. Unsurprisingly, these SNHs are proportionally receiving too many higher penalties (44%) compared to non-SNHs (30%), stimulating the need for re-evaluation of current penalty programs and formulas (Carey & Lin, 2016; Joynt, Figueroa, Oray, & Jha, 2016; Joynt, & Jha, 2013).

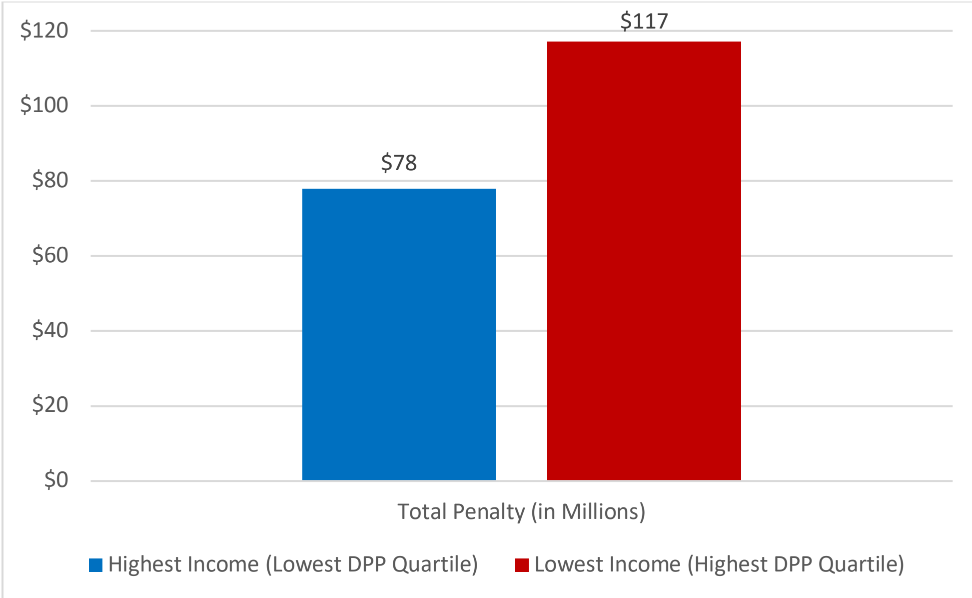

Figure 4.1. Hospitals incurring an HRRP penalty by DPP quartile, FY 15 (DHHS).

Note: Highest income hospitals received $78 million dollars in readmission penalties, compared to the $117 million dollars from hospitals with the lowest income.

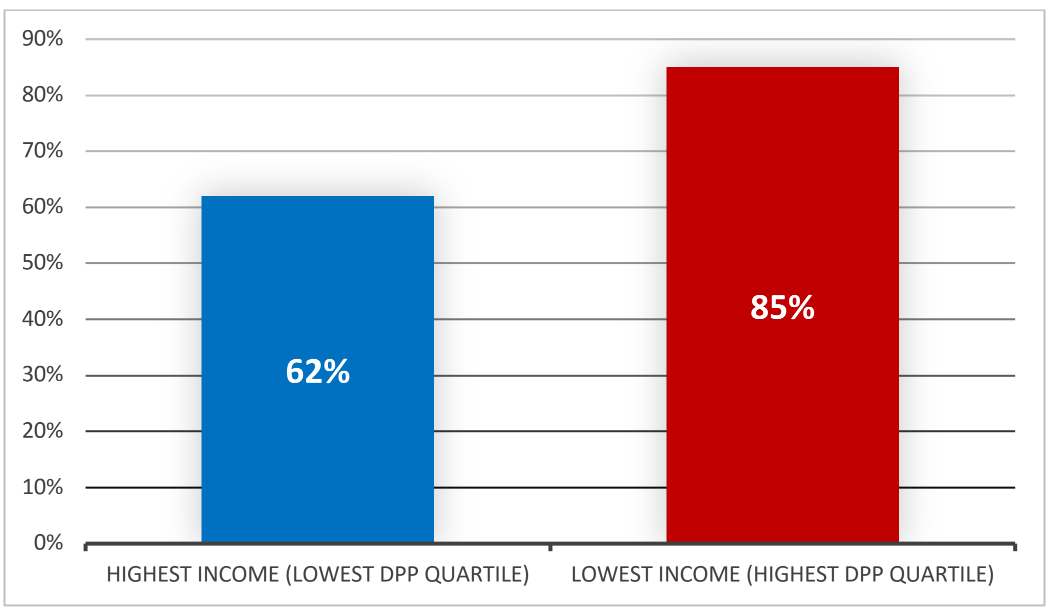

Figure 4.2. Percent penalized by HRRP by DPP quartile FY 15 (DHHS).

Note: 62% of highest income hospitals received readmission penalties, compared to 85% of hospitals with the lowest income.

Assembly of Evidence

Throughout the 2008 election year, health care reform became a significant topic during political debates. Once elected, in response to the need for reduced unnecessary health care spending and improved quality care, President Obama and his cabinet spent the following year gathering teams of experts who methodically drafted a newly designed health care model. Through strong commitment, neutralization of interest group opposition, and carefully calculated advancement of the legislation through a polarized partisan government, on March 21, 2010, the U.S. Patient Protection and Affordable Care Act (ACA) was ratified (Rubin, 2011).

In order to meet the rather hefty legislative goals outlined in the ACA, multiple support programs such as the Hospital Acquired Conditions (HAC), Hospital Value-Based Purchasing Program (VBP), and Hospital Readmission Reduction Program (HRRP) were generated. Penalties occur when hospital claims for services rendered are paid out. Payment adjustments are applied in a tiered order with the Hospital VBP program first, followed by the HRRP, and lastly, the HAC reduction program. The VBP and HRRP adjustments are independent of one another and are applied to the base operating diagnosis-related group (DRG) payment amount. After applying the VBP and HRRP adjustments, the HAC adjustment is then applied to the net result (Wheeler-Bunch, Goubeaux, & Thompson, 2016).

Hospital Value-Based Purchasing (VBP)

Hospital VBP reimbursement penalties began in FY 2013 at 1% of base operating DRGs, met the cap rate of 3% in FY 2015, and continue today (CMS, 2016b). The VBP program consists of various domains, each responsible for a specified weight that is then added to the total sum (CMS, 2012). The domains and their associated weights have evolved considerably over the past four years to better attain the goals of the ACA (Table 4.1; CMS, 2012; DHHS, 2015).

Table 4.1

Hospital Value Based Purchasing Overview

FY	Max Penalty %	Total # of Measures	% Process of Care	% HCAHPS	% Outcomes	% Efficiency	% Safety
2013	1.00%	20	70%	30%	-	-	-
2014	1.25%	24	45%	30%	25%	-	-
2015	1.50%	26	20%	30%	30%	20%	-
2016	1.75%	24	10%	25%	40%	25%	-
2017	2.00%	21	5%[a]	25%	25%[a]	25%	20%
2018	2.00%	20	-	25%	25%[a]	25%	25%

Note: Adapted from https://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNProducts/downloads/Hospital_VBPurchasing_Fact_Sheet_ICN907664.pdf

[a] *Process of Care* and *Outcome* measures were combined into a *Clinical Care* measure

Hospital Readmission Reduction Program (HRRP)

Program overview. With the initiation of the HRRP, the focus on clinical care and outcomes have driven hospitals to reexamine health care delivery. Beginning in October 2012, HRRP began tying patient outcomes to reimbursement for care provided as the CMS (2016a) penalized hospitals with high readmission rates among their fee-for-service Medicare beneficiaries.

Program penalties and measures. Although readmission rates have fallen considerably since 2012, rates for targeted conditions identified by CMS dropped more quickly than non-targeted conditions (Zuckerman, Sheingold, Orav, Ruhter, & Epstein, 2016). In FY 2013 and through FY 2014, CMS included three targeted measures: heart attack, heart failure, and pneumonia. Throughout FY 2015-2016, three additional diagnostic groups were added: chronic obstructive pulmonary disease (COPD), hip replacements, and knee replacements. Most recently, in FY 2017, expansion of pneumonia performance measures and coronary-artery bypass graft (CABG) were added and will continue through FY 2021 (Table 4.2; CMS, 2016b).

Table 4.2

Hospital Readmission Reduction Program Overview

FY	Max Penalty %	Total # of Measures	AMI[a]	HF[b]	PNA[c]	COPD[d]	THA[e]	TKA[f]	CABG[g]
2013	1.00%	3	+	+	+	-	-	-	-
2014	2.00%	3	+	+	+	-	-	-	-
2015	3.00%	6	+	+	+	+	+	+	-
2016	3.00%	6	+	+	+	+	+	+	-
2017	3.00%	7	+	+	+	+	+	+	+
2018	3.00%	7	+	+	+	+	+	+	+

Note: Adapted from https://www.cms.gov/medicare/medicare-fee-for-service-payment/acuteinpatientpps/readmissions-reduction-program.html

[a] Acute Myocardial Infarction
[b] Heart Failure
[c] Pneumonia
[d] Chronic Obstructive Pulmonary Disease
[e] Total Hip Arthroplasty
[f] Total Knee Arthroplasty
[g] Coronary Artery Bypass Graft

In FY16 alone, roughly $420 million in penalties were rendered against 2,600 hospitals for excess 30-day readmissions (Studer Group, 2016). CMS adjusts data related to various demographic characteristics (e.g., xx), then proceeds to calculate a rate of excess readmissions. An examination of Accountable Care Organizations (ACOs) shows organizations with higher racial and ethnic diversity score worse on performance measures—more specifically, scoring much lower on 25 of the 33 measures (Lewis et al., 2017; Shih, Ryan, Gonzalez, & Dimick, 2015).

In 2014, legislators proposed a set of bills requiring CMS to include sociodemographic influences such as age, medical history and other medical conditions in the risk-adjustment methodology embedded in the HRRP. One bill encouraged CMS to examine the potential of expansion of readmission exclusions with the impetus that some patient diagnoses require frequent hospitalizations and some patients are non-compliant, behavior that is out of the providers' control (American Hospital Association [AHA], 2015).

More recently, legislation has been ratified to better protect hospitals with higher portions of low-income beneficiaries as well as large teaching hospitals, which have been shown to receive disproportionate shares of penalties. Adjustments are provided for socioeconomic demographics, including patients who are dually qualified for full Medicare and full Medicaid (Boccuti & Casillas, 2017).

Coronary artery bypass graft measure (CABG). The CABG measure's first performance period began July 1, 2017 and will conclude around December, 2021 after five years. The CABG measure model differs from previous measures as it is part of an Innovation Model in CMS that will take a bundled care approach and initially only be implemented in 98 metropolitan statistical areas (MSAs), including approximately 1,120 hospitals (CMS, 2017). The episode of care begins with hospital admission and concludes 90 days following discharge. Although hospital readmission has not been linked as an independent prognosticator of short-term mortality, readmission data related to cardiac surgery has been substantially high historically (13-18%) and has yet to waver (Hannan et al., 2011; Sargin et al., 2016).

Interest in identifying readmission measures specifically related to surgical patients has grown. Merkow et al. (2015) utilized a dataset from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQUIP) to examine the timing and reason for unplanned readmissions. This prospective study captured 498,875 patients from 346 ACS NSQUIP-associated institutions who underwent bariatric surgery, colectomy/proctectomy, hysterectomy, total hip/knee arthroplasty, ventral hernia repair, and lower extremity vascular bypass in 2012. Across all procedural groups, 5.7% had an unplanned readmission with a median time to readmission of 8 days and an average length of stay of 1 day. Surgical site infection was the leading cause of readmission (19.5%) with ileus or intestinal obstruction as the second (10.3%). Bleeding and anemia were analyzed together, making up the third leading cause of readmission at 4.3% (Merkow et al., 2015).

Focused attention on quality of care delivered to CABG patients is necessary to improve clinical outcomes. Adding CABG to the growing list of CMS-targeted conditions is certainly a step in the right direction; however, design of the inclusion and exclusion criteria is crucial for success.

Constructed Alternatives

Since the initiation of HRRP in 2012, hospital readmissions have continued to be a costly source of concern for many health care organizations. A number of possible alternatives to reduce readmissions exist. First, as risk predictive models expand, such a model would provide organizations with a structure to create processes for identifying and potentially avoiding hospital readmissions following cardiac surgery. Efforts should focus on reducing complications and increasing effective monitoring processes. Second, as factors for increased risk of readmission among post-cardiac surgical patients are identified, use of the care transitions model may also prove helpful in further augmenting post-discharge care and avoiding preventable readmissions (Goldstein, Hicks, Kolm, Weintraub, & Elliott, 2016). Finally, through the examination of factors contributing to the variation in 30-day hospital readmissions following a CABG procedure, a factor-adjusted (e.g., sociodemographic differences) penalty program may be more appropriate.

Predictive Models

One strategy to improve prediction of morbidity and reduce hospital readmissions among postoperative CABG patients is to first identify those patients who are potentially at high risk for poor outcomes. Federal mandates for a comprehensive approach to reducing morbidity and readmissions through the use of evidenced-based predictive models may be a viable option. Patients presenting with multiple comorbidities preoperatively, such as anemia, hypertension, diabetes, heart failure, depression, and alcohol abuse, have a higher rate of morbidity and mortality postoperatively (Humphreys, Denson, Baker, & Tully, 2016; Koch, Weng, Zhou, Savino, Mathew, et al., 2003).

Nashif et al. (1999) first published the European system for cardiac operative risk evaluation instrument (EuroSCORE) that has since aided cardiothoracic surgeons in surgical decision-making, preoperative informed consent, quality assurance, and health care management (Yap et al., 2006). The validity of the EuroSCORE has been tested in tens of thousands of patients and across other countries such as Spain, Turkey, and Australia. While some studies have found its validity satisfactory, overestimation in mortality among high-risk patients has been consistent, requiring clinicians and researchers to continue work on finding a more reliable methods of risk evaluation.

Researchers in Columbia considered the addition of hemoglobin and B-type natriuretic peptide (BNP) to the EuroSCORE to see if the predictive power of morbidity and mortality would be increased for both index hospitalizations and 60-day readmissions. Hernández Leiva, Dennis, Isaza, and Umaña (2013) reviewed data on 492 patients, looking at the predictability of hemoglobin and BNP independently against the EuroSCORE, then they incorporated the variables into the EuroSCORE itself. Findings showed that independently, neither hemoglobin nor BNP were strong predictors of morbidity or mortality. When both variables were integrated, the EuroSCORE increased prediction of morbidity, particularly transfusion; however, mortality predication was not significantly improved.

Espinoza et al. (2016) published a simplified risk prediction instrument that could be used to better identify patients at high risk for early hospital readmission following open-heart surgery. The instrument was tested and validated in Argentina on more than 5,000 patients (AUC 0.639 [95% CI 0.606 to 0.672]). The instrument procedure includes a review of the preoperative hematocrit, with a value of <35% preoperatively considered high risk. Other items on the instrument include a history of diabetes mellitus, minutes spent on-pump, highest serum glycemic level, and atrial fibrillation postoperatively. The authors admitted the instrument was limited by poor exploration of preoperative anemia, and they discussed the association between acute kidney injury (AKI) and anemia, with supporting evidence that AKI is a precursor to other risk factors associated with hospital readmission. Using multivariate analysis for determining readmission risk, results showed neither preoperative renal failure nor postoperative acute kidney injury were strongly associated with hospital readmission. However, upon examination of preoperative anemia alone, uni- and multivariate analysis showed a significant association with hospital readmission (Espinoza et al., 2016).

While some instruments have been shown to overestimate the morbidity and mortality risk of preoperative candidates, mandatory implementation of a validated risk predictor instrument during preoperative assessment remains a promising approach to decrease readmissions and morbidity upstream by preventing high-risk patients from undergoing risky surgery in the first place.

Care Transitions Programs

Care transitions programs have demonstrated effective reduction in overall hospitalizations (11%) and hospital readmissions (15%) among Medicare beneficiaries (Lynn, 2014). Nurse practitioners who provided follow up care at the patient's home following CABG procedures significantly reduced 30-day readmission/death rate (3.85%) compared to usual care (11.54%; Hall et al., 2014). Older adults undergoing CABG surgery are at an increased risk for depression and decreased functional status (Sorenson & Wang, 2009). Physical therapists have carved a role into care transitions programs through improving functional status of discharged CABG patients in the home setting (Arthur, Smith, Kodis, & McKelvie, 2002). Providing state and federal funding for care transition programs could stimulate creation and utilization of such programs and further reduce undesired patient outcomes.

Adjusting for Factors

Readjustments for age, medical history, and other medical conditions currently exist in the adjustment methodology within cardiac surgery risk prediction instruments however, an opportunity exists to add poverty and community factors that also affect hospital readmission risk. Some experts working in CMS and the National Quality Forum (NQF) argue adjusting for sociodemographic factors may mask disparities through the softening of penalties and lowering of standards and could unintentionally deter incentives to improving health outcomes for disparate populations (AHA, 2015; U.S. Government Publishing Office [GPO], 2016). While this concern is valid, funding is at risk for safety-net hospitals that primarily care for patients holding state and federal insurance, and funding will be at even greater risk when Medicare-Medicaid funding is cut for disparate groups through decreased insurance coverage while the penalty methodology remains the same.

Postoperative patients with Medicare-Medicaid insurance have increased mortality rates and longer hospitalizations and are more likely to have multiple comorbidities preoperatively with fewer resources postoperatively (Herrel, Wong, Ye & Miller, 2016). While adjusting penalties for facility-specific payor mix may not drastically improve patient outcomes, an adjustment for patients with Medicare-Medicaid insurance has been shown to better represent socioeconomic disparities and predict readmissions (Anderson, Li, Romano, Parker, & Chang, 2016). After taking patients' poverty status into consideration within the calculated adjustment methodology, Missouri hospitals' readmissions rates showed marked improvement (43% to 88%; Gillespie, 2016).

Select the Criteria

The CMS reported that section 3025 of the Affordable Care Act required establishment of the HRRP to reduce payments to Inpatient Prospective Payment System (IPPS) hospitals with excessive readmissions starting in FY 2013 (October 1, 2012;

CMS, 2016a). Using the risk adjustment methodology sanctioned by the National Quality Forum, readmissions measures were calculated as a ratio of X to Y and were fine-tuned taking into consideration clinically appropriate components including specific “patient demographic characteristics, comorbidities, and patient frailty” (CMS, 2016a). For FY 2013, the maximum penalty for excess 30-day hospital readmission was set at 1%. The penalty increased incrementally to 2% in FY 2014 and reached a cap of 3% in FY 2015, which remains today.

Historically, the health care system has taken extensive time to implement comprehensive programs that address patient outcomes (CMS 2016a). Since the initiation of the HRRP, concentrated efforts focusing on the reduction of morbidity and readmissions have pushed hospitals to implement risk reduction programs at a much quicker pace, and results show favorable outcomes in decreased costs and improved quality of life (Keenan et al., 2008). With the addition of CABG as a targeted measure, it can be expected readmission rates will decrease; however, sociodemographic data must be considered, as many patients will present with multiple comorbidities and have poor compliance, thus challenging which outcomes are truly within the control of health care providers.

Decreasing readmissions among the postoperative CABG population—through increased accountability efforts designated by the HRRP and implementation of a care transition approach—is likely to have profound effects similar to or perhaps greater than those of other established CMS-targeted conditions. Organizations providing open-heart surgical services must be prepared to redesign their programs to incorporate additional services (e.g., predictive models and care transitions programs) upstream to prevent negative downstream consequences for example hospital readmissions. In addition, increased interprofessional collaboration will provide patients with enhanced comprehensive care throughout their hospitalization and even following them home, thus optimizing patient recovery and preventing readmissions. Nurses, including advanced practice nurses (APRNs), must be empowered to maximize processes where care can be rendered effectively and efficiently throughout patient episodes of care.

Projected Outcomes

In 2007, the Medicare Payment Advisory Commission (MedPAC) presented Congress with a report outlining the top seven potentially preventable medical conditions (MedPAC, 2007). Of the seven, CABG ranked among the top potentially preventable readmission conditions at 13.5% (Yale New Haven Health Services Corporation/Center for Outcomes Research & Evaluation [YNHHSC/CORE], 2014).

The volume of CABG procedures has been consistently declining since the mid 2000s. In 2014, the Society of Thoracic Surgeons (2015) counted more than 171,000 isolated and combined CABG procedures across the United States. At an average readmission rate of 13.5%, this would account for 23,085 30-day hospital readmissions annually. Although predictions have not been set for the reduction of CABG readmissions, we can examine the performance of previously set targeted conditions to gain a better understanding of how CABG readmissions might change. Between 2006 and 2014, readmission rates fell for heart failure by 11% (24.8 to 22.0), myocardial infarction by 14.6% (19.9 to 17.0), and pneumonia by 8.6% (18.5 to 16.9; Boccuti & Casillas, 2017). Applying these reduction rates (8.6-14.6) to the CABG population would result in a readmission rate ranging between 19,715-21,100 patients annually.

Even though it is not known what percentage of CABG patients are living in poverty, we can estimate the majority are likely covered by Medicare-Medicaid, had complex comorbidities prior to surgery, and had reduced resources postoperatively. Incorporation of social demographics into the calculated adjustment methodology would certainly lower the overall readmission rate penalties.

Confronting Trade-Offs

Mandated application of predictive models into preoperative assessments can reduce the number of patients with poor surgical outcomes, including hospital readmissions. However, this also means the number of surgical cases will likely decline overall because patients may no longer be candidates for surgery according to preoperative assessment findings. CABG surgery is a very profitable service for many hospitals. Reduction in cases will lead to less profit upfront, but the downstream effect is that fewer reimbursed dollars will be spent on readmission care, and penalties must be considered.

Implementation of a care transition program will be costly up front; program development, staffing, and work flow will need to be addressed. Restructuring patient discharges to create more effective transitions in care will likely modify the current roles of various professionals that may be an initial barrier to successful change. Over time and when role competence is achieved, the transition of care should be efficient and result in improved outcomes, including declining readmission rates.

Adjusting for reimbursement models for insurance to help relieve safety-net hospitals from burdening financial penalties may diminish hospitals' efforts to create and implement readmission reduction programs. Conversely, if financial penalties are reduced for safety-net hospitals, cost avoidance savings may drive readmission reduction processes, including preventative care efforts, resulting in worse outcomes.

Recommendations

The 2011 Institute of Medicine (IOM) report charges nurses to become full partners with physicians and other health care professionals in the redesign of health care in the United States. To improve quality of care and patient outcomes, nurses must become creative in our solutions and strengthen our voice. With over 3.1 million nurses practicing across a wide variety of settings, we are familiar with deficits in health care, resource limitations, and patient needs. This knowledge can drive the development of meaningful programs. Creating preventative care programs designed to reach patients in lower socioeconomic areas can improve overall population health by reducing comorbidities and devastating chronic illnesses.

Implementation of predictive care models in cardiovascular surgical programs can assist providers in proactively mitigating potential complications identified through preoperative assessment using evidence-based predictive assessment instruments. Nurses functioning as case managers for these patients can assist in the application of predictive care models through patient assessment and delivery of formal recommendations to consulting physicians.

Application of strong transitions of care programs can influence patient behaviors to improve compliance and long-term health. Both RNs and APRNs certainly have a role within these programs. From assessing and teaching to diagnosing and treating, nurses are important in the effort to develop and implement successful transitions programs.

Conclusion

Patients undergoing CABG procedures are faced with a higher than normal likelihood of experiencing a hospital readmission 30 days of discharge. As hospitals work to improve readmission rates, upstream determinants must be carefully assessed and addressed to see positive downstream changes. It is imperative policy makers include nursing at the table as a stakeholder.

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CHAPTER V

DISCUSSION OF FINDINGS

Background and Study Purpose

Each year, more than 500,000 cardiac surgery procedures take place in the United States (Texas Heart Institute, 2019a). While the number of coronary artery bypass graft (CABG) procedures has decreased over the years, they still comprise nearly half of all adult open-heart surgery procedures at more than 200,000 surgeries annually (Benjamin et al., 2018; Texas Heart Institute, 2019a). In contrast, valve-related procedures are steadily increasing in numbers, contributing to more than 106,000 procedures per year (Texas Heart Institute, 2019b). As the U.S. baby boomer population continues to age, the number of cardiac-related procedures is expected to increase significantly. Federal efforts to improve access to care, the patient experience, and better outcomes afforded by lower costs have shifted the way organizations do business. Deemed a performance measure by the Centers for Medicare and Medicaid Services (CMS) in 2017, efforts to improve patient outcomes following coronary artery bypass surgery have become a focus for U.S. hospitals.

Hospital readmissions among cardiac surgery patients are higher than most surgical procedures and contribute a significant financial burden to individuals and the health care system (Hannan et al., 2011; Mozaffarian et al., 2016; Sargin et al., 2016). A common criticism of CMS' Hospital Readmission Reduction Program (HRRP) is its lack of attention to safety-net hospitals. Efforts have been made to create and refine risk prediction models that could better direct clinicians in their approach to patient care. While risk prediction model development carries unique challenges, namely the quantity of potential confounding variables to take into consideration, a few well-tested models do exist in practice today (D'Agostino et al., 2018). Inclusion of sociodemographics within risk predication models may add value to the accuracy of risk calculations and better support safety-net hospitals who care for underserved populations.

Synthesis of Dissertation

Application of Condition-Based Maintenance: A Concept Analysis

Chapter 2 presented a concept analysis completed using Walker and Avant's (2011) eight-step concept analysis procedure. When deriving a concept for analysis related to the topics of symptom science and hospital readmissions, concepts and models were examined from a wide range of industries that dealt with the general idea of "maintenance" and "failure" within their field. Articles within engineering were overwhelmingly filled with maintenance models. These models were examined, and the lifespan of equipment and related maintenance was closely reviewed and compared to the health care delivery model. However, use of condition-based maintenance has not been explored in relation to health maintenance among humans. The aims of the concept analysis were to develop an operational definition of the term *condition-based maintenance* as applied to health care and to discuss the applicability and effectiveness of condition-based maintenance within health care.

Condition-based maintenance was defined as an efficient, proactive process utilizing monitoring methods to predict, identify, and repair health-related problems precisely, therefore lengthening one's life. Application of the condition-based maintenance model may prove to have relevance in reducing hospital readmissions as it relates to the monitoring, identification, and treatment of specific disease processes before an individual experiences a significant decline in health, warranting care. This concept analysis advances the NINR’s focus on symptom science through the development of personalized strategies to treat and prevent the adverse symptoms of illness. It is anticipated this concept analysis will contribute to further identification of clinical signs of deterioration and accompanying interventions to prevent hospitalization and unnecessary death.

Preoperative Anemia and 30-Day Hospital Readmission Among Adult Postoperative Open-Heart Surgery Patients

Chapter 3 presented a research study conducted to examine the prevalence and postoperative outcomes of iron-deficiency anemia on adults undergoing open-heart surgery. To better understand this relationship, the research question of interest was, *What is the relationship between preoperative anemia (hemoglobin<13g/dL), and 30-day hospital readmission among adult postoperative open-heart patients?*

A descriptive, correlational, cross-sectional design was used for the study. This design enabled the identification of many interrelationships among variables within a specific condition at one point in time. The study provides valuable insights into the use of a correlational, cross-sectional study for testing the hypotheses in data related to preoperative anemia and surgical outcomes following open-heart surgery in an adult population. In this study, significant patient characteristics and their association with preoperative anemia and 30-day hospital readmission were identified. In total, 1,353 cases of surgeries performed between August 2014 and July 2018 were extracted from the Society of Thoracic Surgeons National Database for Adult Cardiac Surgery from three participating southern California facilities.

Research aim I. The first research aim was to identify the prevalence of adult patients presenting with anemia preoperatively at three community-based hospitals located in the southwestern region of the United States. The study found a prevalence rate of 44% among adult patients presenting with preoperative anemia, consistent with previous research examining preoperative anemia in the adult cardiac surgery population (Dai et al., 2018; Hubert et al., 2019; Karkouti et al., 2008; Kulier et al., 2007; Musallam et al., 2011; Nuis et al., 2013). Among those with preoperative anemia, 28% were classified as mild, 15% as moderate, and 1% as severe. This distribution of preoperative anemia was similar to findings reported in the literature as well (Nuis et al., 2013).

Research aim II. The second aim examined the relationship between preoperative anemia, sociodemographics, and 30-day hospital readmission rates among postoperative open-heart adult patients. A total of 177 patients with preoperative anemia were readmitted to the hospital within 30 days of discharge. Of the 14 predictor variables, only six were identified as statistically significant: (a) hospital admission source, (b) hypertension, (c) tobacco use, (d) preoperative anemia, (e) reason for urgent or emergent surgery, and (f) intra-aortic balloon pump (IABP). When compared to patients with an elective admission to the hospital, those admitted to the hospital through the emergency department were 6.86 times (95% *CI* 2.04, 23.09) more likely to be readmitted to the hospital in the first 30-days after hospital discharge; those transferred from another hospital, acute care facility, or any other facility were 7.67 times (95% *CI* 1.82, 32.35) more likely to be readmitted. Patients with hypertension were 9.53 times (95% *CI* 1.86, 51.47) more likely to be readmitted. Patients who used tobacco products were 2.53 times (95% *CI* 1.37, 4.68) more likely to be readmitted. When compared to patients with no anemia, patients with mild anemia were 2.31 times (95% *CI* 1.06, 5.01) more likely to be readmitted; those with severe anemia were 16.99 times (95% *CI* 1.42, 201.71) more likely to be readmitted. When compared to patients that had an urgent or emergent surgery reason of acute myocardial infarction (AMI), ongoing ischemia, unstable angina (USA), worsening chest pain (CP), rest angina, or syncope, those with an urgent or emergent surgery reason of anatomy, intra cardiac mass or thrombus, or a valve dysfunction were 4.46 times (95% CI 1.26, 15.82) more likely to be readmitted. Finally, patients who had an IABP were 3.16 times (95% CI 1.55, 6.44) more likely to be readmitted.

Coronary Artery Bypass Grafting and the Hospital Readmission Reduction Program

As previously stated, the costs and related readmissions associated with open-heart surgery are considerably high relative to other common surgical procedures (MedPAC, 2007; Mozaffarian et al., 2016). Chapter 4, the third manuscript of this project, followed Bardach and Patashnik's (2016) eight-step policy analysis procedure. The two aims of this analysis were to explain the development and impact of the Hospital Readmission Reduction Program (HRRP) and to discuss the political, social, and economic implications of coronary artery bypass grafting as a newly targeted condition within the HRRP. The HRRP began penalizing hospitals in FY 2013 on just three measures, but since that time the number of measures has grown to seven and the percent penalized has climbed from 1% up to 3%.

CABG procedure was recently added as a targeted measure in FY 2017. Through the addition of CABG as a targeted measure, it can be expected that readmission rates will decrease; however, social demographic data must be taken into consideration as many patients will present with multiple comorbidities and poor compliance, thus challenging what outcomes are truly within the control of health care providers. Adjusting reimbursement models for insurance may help relieve safety-net hospitals from burdening financial penalties.

Discussion

The concept analysis of condition-based maintenance presented in Chapter 2 underpins the importance of symptom science through the transposing and trialing of established monitoring methods to improve patient safety, increase life-span, decrease burden, and decrease health care costs. This concept analysis is considered innovative, but it is also abstract in nature. Without applicable empirical referents, further research is needed to identify whether condition-based maintenance can be adapted to monitoring various human conditions effectively. Additional quantitative and qualitative research focusing on both disease-specific measurements and quality of life components could further develop the concept in becoming more operational. Outcomes from this analysis may be useful in the development and testing of measurement instruments.

In the empirical study presented in Chapter 3, the prevalence of preoperative anemia was 44%, and prevalence was higher in Black, Hispanic, and Asian/Pacific Islander patient populations. Burton et al. (2019) concluded preoperative anemia may not only be associated with racial differences and a higher comorbidity burden but may also increase the likelihood of postoperative morbidity and mortality. This study did not examine the relationship between race, morbidity, and mortality directly.

The greater part of cases in this study (76%) identified Medicare as the primary payor. Considering Medicare is available to persons 65 years and older, and the majority of adult patients undergoing open-heart surgery are also 65 and older, it is no surprise Medicare is the primary payor (Karkouti et al., 20018; Nuis et al., 2013).

Gender plays a key role in preoperative anemia and postoperative morbidity and mortality outcomes. While there were more male than female cases in this study, females had a considerably higher incidence of preoperative anemia, yet readmission rates between genders remained relatively equal. Raju et al. (2018) noted an association between preoperative hemoglobin levels of both genders and in-hospital mortality, adverse cardiac events, and postoperative complications, with males having a higher risk overall.

Little is known about the influence of surgical admitting source and clinical outcomes among patients undergoing open-heart surgery. In this study, patients admitted to the hospital for surgery electively had a lower preoperative anemia rate than patients admitted through the emergency department or as an outside transfer from another facility. Additionally, patients who required open-heart surgery urgently had a higher prevalence of preoperative anemia than their electively scheduled counterparts.

Patients with preoperative anemia are at a higher risk for red blood cell transfusion both perioperatively and postoperatively that is associated with adverse clinical outcomes (Hubert et al., 2019; Mirzaei, Hershberger & DeVon, 2019). This is consistent with the findings of this study, showing an association exists between preoperative anemia and red blood cell transfusion both perioperatively and postoperatively.

Guidelines for blood product use in cardiac surgery patients have been established for well over a decade in the United States. Ferraris et al. (2007) identified six variables to serve as critical indicators of risk: (a) advanced age, (b) low preoperative red blood cell volume (preoperative anemia or small body size), (c) preoperative antiplatelet or antithrombotic drugs, (d) preoperative or complex procedures, (e) emergency operations, and (f) non-cardiac patient comorbidities. In this study, patients identified as anemic preoperatively had a much higher probability of receiving blood product transfusion perioperatively. Only 37% of patients who did not have anemia received a perioperative transfusion, compared to 57% of patients with mild anemia, 83% of patients with moderate anemia, and 89 % of severely anemic patients (Hung et al., 2011; Karkouti et al., 2008; Von Heymann et al., 2016). Many of the patients who received blood product transfusions in this study met several if not all six criteria.

Implementation of risk prediction instruments that contain evidenced-based transfusion risk criteria is critical for improved patient outcomes. Blood management programs now exist worldwide and are aimed at supporting organizations and multidisciplinary clinicians examine their current practices and opportunities for improvement in their use of blood products (Mueller et al., 2019). Implementation of a blood management program has been shown to reduce adverse patient outcomes and provide organizations considerable cost savings (Gross, Seifert, Hofmann, & Spahn, 2015; Meybohm et al., 2016; Leahy et al., 2017; Scolletta et al., 2019). Reviewing patient risk factors for blood product transfusion, including anemia, and providing treatment preoperatively is crucial. Jin el al. (2019) examined the benefits of intravenous iron administration on preoperative anemic patients showing a reduction in blood product transfusions and a correlation with decreased length of stay. Local policies and procedures should include such practices in attempt to improve patient outcomes.

Upon examination of the results, the investigator identified a higher percentage of patients with preoperative anemia being discharged to an extended care or transitional unit, nursing home, or other acute care facility. While there is no literature specifically focusing on the association between preoperative anemia and discharge locations, one can assume patients discharging to a facility other than home are more ill and require care from licensed professionals as a result.

Cho et al. (2019) suggest an association exists between patients with severe anemia (hb <8g/dL) at discharge and 30-day hospital readmission. This was also a finding in this study; patients with preoperative anemia were more likely to incur a 30-day hospital readmission. Of patients readmitted within 30 days, those identified as having preoperative anemia were more likely to come back to the hospital for an anticoagulation problem, chest pain, congestive heart failure (CHF), deep vein thrombosis (DVT), infection of the conduit harvest site, pericardial effusion, respiratory complications, sepsis, endocarditis, or other reasons, both surgical and non-surgical related. To date, the investigator has not found literature examining the association between preoperative anemia and the reasons specified for 30-day hospital readmission.

This study had several strengths and limitations. A cross-sectional study design was particularly suitable for this study as the research question sought to understand the prevalence of preoperative anemia in the adult cardiac surgery population. The study design allowed the investigator to examine many risk factors, including sociodemographics, and assess more than one outcome. Over a four-year period, August

2014 through July 2018, the study yielded 1,353 cases, an adequate sample size considering the large number of variables. While this study examined several demographic, comorbidity, surgical and transfusion criteria, an important limitation was the lack of adjustment for perioperative and postoperative surgical bleeding. This data was not included in the STS database extraction because literature supporting its use was identified after the database was built. Tauriainen, Koski-Vähälä, Kinnunen, and Biancari (2017 found adverse events were no longer associated with preoperative anemia when adjusted for key baseline criterion, procedural components, surgical bleeding, and blood product transfusion.

The Society of Thoracic Surgeons refer to data managers as the primary source of data input. Data managers review training modules and have access to several online resources to help manage the data input process. Nonetheless, caution must be noted for the accuracy of the collected data. To the best of the investigator's knowledge, no interrater reliability testing has been performed. The investigator could not validate the accuracy of data set values.

Nursing Implications

Decreasing readmissions among the postoperative CABG population through increased accountability efforts designated by the HRRP is likely to have profound effects similar to or perhaps greater than those of other established CMS-targeted conditions. Organizations providing open-heart surgical services must be prepared to redesign their programs to incorporate additional services (e.g., predictive models and care transitions programs) upstream to prevent negative downstream consequences such as hospital readmission. Increased interprofessional collaboration will provide patients with enhanced comprehensive care throughout their hospitalization and even following them home, thus optimizing patient recovery. Nurses, including advanced practice nurses (APRNs), must be empowered to maximize processes where care can be rendered effectively and efficiently throughout patient episodes of care.

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APPENDIX

University of San Diego Institutional Review Board Summary

Jul 25, 2018 9:45 AM PDT

Lindsey Ryan
Hahn School of Nursing & Health Science

Re: Exempt - Initial - IRB-2018-481, Chronic Anemia and Hospital Readmission among Postoperative Open-Heart Patients

Dear Lindsey Ryan:

The Institutional Review Board has rendered the decision below for IRB-2018-481, Chronic Anemia and Hospital Readmission among Postoperative Open-Heart Patients.

Decision: Exempt

Selected Category: Category 4. Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

Findings: None

Research Notes:

Internal Notes:

Note: We send IRB correspondence regarding student research to the faculty advisor, who bears the ultimate responsibility for the conduct of the research. We request that the faculty advisor share this correspondence with the student researcher.

The next deadline for submitting project proposals to the Provost's Office for full review is N/A. You may submit a project proposal for expedited or exempt review at any time.

Sincerely,

Dr. Thomas R. Herrinton
Administrator, Institutional Review Board

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