The Perceived Impact of ICU Work Environment on Continuous Renal Replacement Therapy (CRRT) Practice, ICU Nurses' Performance, Quality of Care, and Patient Safety in Adult ICUs: A Mixed Methods Study

By

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Dedication

To Hadiah Ahmad and Seed Bin Ali, my parents, I dedicate this dissertation to you.

A thank you is not and will never be enough to express my gratitude to both of you for believing in me and giving me the opportunity to become who I am today.

May your soul rest in peace, Dad

And

May you celebrate more successes with me, Mom.

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Lastly and most importantly, I want to thank my study participants, ICU nurses, for their contributions to this research. I am indebted to them for taking time from their busy schedules to share with me their stories and thoughts. I am inspired by their dedication and hard work to provide quality CRRT care to their patients.

Abstract

TITLE: The Perceived Impact of ICU Work Environment on, Continuous Renal Replacement Therapy (CRRT) Practice, ICU Nurses' Performance, Quality of Care, and Patient Safety in Adult ICUs: A Mixed Methods Study

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The specific aims of this exploratory sequential mixed methods study were to 1) describe the impact of the ICU work environment on CRRT nursing practice and ICU nurses' performance, quality of care, and patient safety; 2) identify ICU nurses' perceptions of factors in the ICU work environment that influence their performance when managing CRRT and affect quality and safety outcomes; 3) generate a substantive grounded theory of the ICU work environment and CRRT nursing practice; and 4) develop and test an instrument to measure the perceived impact of the ICU work environment on CRRT nursing practice, quality of care, and patient safety. This was a two-phase study where one phase sequentially occurred after the other. Phase one was a qualitative study, Dimensional Analysis Grounded Theory. Fourteen ICU nurses were interviewed in this phase and analysis of qualitative data produced 15 dimensions: three contexts (the ICU Environment, CRRT machine, patient), five conditions (staffing and support, team role definition and communication, training and competency and CRRT frequency, workload, patient and family needs), four processes (starting a patient on CRRT, safeguarding patients, knowing what to do, staying on top of things), and three outcomes (performance, quality of care, safety).

These 15 dimensions guided the development of the Nurse's ICU-CRRT Environment (NICE) scale in phase two. Content validity was established via expert panel feedback (S-CVI/Ave=0.92). The NICE scale was pilot tested and later was tested nationally to establish its psychometric properties. A national sample of ICU nurses (n= 308) completed the questionnaire via REDCap and an exploratory factor analysis using, PCA, revealed a six factor solution with 20 items. These factors were CRRT machine functionality, CRRT machine technicality, staffing and support, communication and coordination, safeguarding, and training. Although the structure of the new instrument did not mirror the theoretical model, the final solution represents to a great degree the dimensions of the ICU work environment and CRRT practice. Convergent validity was established by a establishing an inverse significant association between the NICE scale and workload as measured by the NASA-TLX scale. The NICE scale includes satisfaction subscale (3 items), which correlates positively with the 20 items.

The NICE scale appears to be a reliable instrument. Overall scale reliability has a Cronbach's alpha of 0.794 and Cronbach's alpha scores for the subscales range between 0.557 and 0.767. Three subscales had Cronbach's alpha scores of below 0.7 (i.e., CRRT machine functionality $\alpha = 0.694$, communication and coordination $\alpha = 0.629$, and training $\alpha = 0.557$). Despite the low alpha scores, these three subscales are important in the ICU-CRRT context. Therefore, all subscales will be kept and used in future research.

Table of Contents

Dedication iii
Acknowledgment of Financial Support iv
Acknowledgement v
Abstract vi
List of Tables xiv
List of Figures xv
CHAPTER ONE 1
Introduction 1
Significance to Nursing 5
Purpose of the Study 6
Research Questions 7
Specific Aims 8
CHAPTER TWO 10
Literature Review 10
Acute Kidney Injury (AKI): A Common and Complex Condition 10
Definition of AKI 10
AKI Prevalence Rate and Statistics 13
Continuous renal replacement therapy (CRRT): A Multidimensional and Complex Process 15
The Idea of CRRT 15
ICU Nurse Responsibilities 19
CRRT: Training and Competency 21
The ICU Work Environment 22
The Balance Theory, the Work System Model, and the Systems Engineering Initiative for Patient Safety (SEIPS) Model of Work System and Patient Safety 22
The Impact of the ICU Working Environment 28
Teamwork. 28
Communication. 30
Workload. 31
Physical environment. 31
Nurses Performance and Work Environment Measurements 32
Nurse Performance Measurements 32

The Six-Dimension Scale of Nursing Performance (SDNS). 33
The Job Performance Scale (JPS). 34
The Slater Nursing Competencies Rating Scale (SRS). 35
The King's Nurse Performance Scale (KNPS). 36
Performance Obstacles Scale 37
Work Environment Measurements 39
The Nursing Work Index (NWI). 40
NWI-Revised (NWI-R). 41
The Practice Environment Scale of the Nursing Work Index (PES-NWI). 42
The Perceived Nursing Work Environment (PNWE). 43
The Practice Environment Index (PEI). 44
The Work Environment Scale (WES). 44
ICU Nurse-Physician Questionnaire. 45
The Healthy Work Environment (HWE) Instrument. 47
The Healthy Workplace Index (HWPI). 47
The Job Characteristics Inventory (JCI). 48
The Ward Organization Features Scale (WOFS). 49
The Professional Practice Environment (PPE) Scale. 50
The Work Quality Index (WQI). 52
The Assessment of Work Environment Schedule (AWES). 52
Conclusion 54
CHAPTER THREE 55
Methodology 55
Mixed Methods Research 56
Definitions of Mixed Methods 57
The Historical Foundations of Mixed Methods Research 58
Reasons for Mixing Methods 59
Mixed Methods Research Designs Typology 63
Exploratory Sequential Mixed Methods Design 64
Philosophical Assumptions 65
Phase One: Dimensional Analysis (DA) Grounded Theory 66
Development of DA 67

The Process of DA 69
Setting 72
Sample and Sampling 72
Recruitment 73
Procedure 74
Data Collection 75
Data Analysis 77
Evaluation of Grounded Theory 79
Phase Two: Instrument Development and Testing 81
Scale Development 81
Sample and Sampling 82
Pilot study. 82
National study. 82
Recruitment 82
Pilot study. 82
National study. 83
Procedure 83
Pilot study. 83
National Study. 84
Data Analysis 85
Scale reliability. 86
Scale validity. 86
Human Subjects 88
CHAPTER FOUR 90
Results 90
Grounded Theory: The ICU-CRRT Practice Theory 90
Sample 91
Sample demographics. 91
Applying the DA Approach 94
Perspective. 94
Contexts. 97
Patient 97

The CRRT machine. 97
The ICU environment. 99
Interactions among the ICU environment, CRRT machine, and patient. 101
Conditions. 102
Conditions related to the ICU environment. 102
Staffing. 102
Support. 103
Role of intensivists and the nephrology team. 105
Communication. 106
Conditions related to the CRRT machine. 107
Training and knowledge. The ICU 107
Competency and CRRT frequency. 109
Conditions related to the patient. 111
Workload. 111
Patient and family needs. CRRT 112
Processes. 113
Starting a patient on CRRT. 113
Safeguarding patients. 116
Knowing what to do. 118
Staying on top of things. 120
Consequences. 122
Quality consequences. 122
Safety consequences. 123
Performance consequences. The ICU nurses 124
The Nurse's ICU-CRRT Environment (NICE) Scale 126
Transforming Qualitative Codes and Quotes into Items 126
Assessing Content Validity 127
Calculating the Content Validity Index (CVI) 128
Revising Items and Creating an Instrument 128
Pilot Testing the New Instrument 131
Sample characteristics. 134
Reliability. 136

Revising the Survey and Administering it to a National Sample 137
Sample characteristics. Intensive care unit 137
Assessing Reliability and Validity 139
Confirming the Final Structure of the New Instrument 146
Descriptive analysis and correlations. 146
The Nurse's ICU-CRRT Environment (NICE) Scale. 146
Workload and NICE scale. 148
Correlations between the NICE scale and NASA-TLX scale. 149
Summary 149
CHAPTER FIVE 151
Discussion of the Findings 151
The ICU-CRRT Practice Theory 151
The ICU as a Working Environment 152
Characteristics of ICUs. 152
Physical environment. ICU 152
Communication and team role definition. 153
Staffing and support. 154
Workload. The ICU 154
The CRRT Machine 155
CRRT Machine evolution. 155
Training and competency. 156
Coordinating supplies. 157
Errors and adverse events. 158
Starting a Patient on CRRT 159
Patient characteristics and family needs. 159
Late versus early initiation of therapy: a medical decision. 160
Delays in connecting a patient to a CRRT machine. 160
Comparing the ICU-CRRT Practice Theory to Other Models 161
Strengths and Limitations 166
Implications 167
Implications for Practice 167
Implications for Education 167

Implications for Research 168
References 169
Appendices 195
Appendix 1- Site Approval Letter ..... **Error! Bookmark not defined.**
Appendix 2 - OHSU IRB Approvals ..... **Error! Bookmark not defined.**
Appendix 3- Telephone Recruitment and Screening Script Template 198
Appendix 4- Qualitative Study Information Sheet 200
Appendix 5- Qualitative Study Demographic Questions 202
Appendix 6- Interview Guide 203
Appendix 7- Pilot Study Information Sheet 205
Appendix 8- AACN Study Invitation Postcard 207
Appendix 9- National Study Information Sheet 208
Appendix 10- NASA Task Load Index (NASA-TLX) Scale 210
Appendix 11- ICU Work Environment and CRRT Questionnaire 211
Appendix 12- The NICE scale 217

List of Tables

Table 4.1 Study Sample Demographics ……..……...… 93

Table 4.2. The new instrument's subscales and the number of items in each subscale ……. 131

Table 4.3 Mean scores and percent missing for the individual items …… 132

Table 4.4. Pilot study sample demographics …….……. 135

Table 4.5. Cronbach's alphas for each subscale (dimension)……. 136

Table 4.6. National study sample demographics ……..…. 138

Table 4.7. KMO and Bartlett's test results ……..…….…. 141

Table 4.8. Total variance explained …….……..…….…. 142

Table 4.9. Summary of factor analysis of six factor solution (rotated matrix)……... 145

Table 4.10. CRRT practice descriptive statistics ……..….. 148

Table 4.11. NASA-TLX descriptive statistics ……..….. 149

Table 5.1. Comparison between qualitative and quantitative results …….…..... 165

List of Figures

Figure 2.1. RIFLE and AKIN classifications for AKI ……..……..…13

Figure 2.2. A Continuous Venoenous Hemofiltration System ……..…….…….16

Figure 2.3. The Balance Theory ……..……....23

Figure 2.4. The Work System Model …….…….……..…..25

Figure 2.5. The SEIPS 2.0 Model …….…….……....…28

Figure 3.1. The Exploratory Sequential Mixed Methods Study Design ……..…..…..65

Figure 3.2. The Explanatory matrix …….…….…….…..…….……...71

Figure 4.1. The ICU-CRRT Practice Model …….…..……94

Figure 4.2. Scree plot …….……...…143

CHAPTER ONE

Introduction

Acute kidney injury (AKI), characterized by a sudden deterioration in renal function, is a life-threatening complication of critical illness (Carl, Grossman, Behnke, Sessler, & Gehr, 2010; Lameire et al., 2013; Susantitaphong et al., 2013; Warnock, 2005). More than 300,000 Americans are diagnosed with AKI each year (ASN, 2016) at a prevalence greater than 60% during intensive care unit (ICU) admissions (Baldwin & Fealy, 2009; Chertow, 2005; Susantitaphong et al., 2013; Uchino, 2010; Waikar, Liu, & Chertow, 2008; Warnock, 2005). AKI is positively correlated with increased mortality, morbidity, and healthcare costs, with a reported mortality of more than 50% (Carl et al., 2010; Lameire et al., 2013; Susantitaphong et al., 2013; Waikar et al., 2008). The estimated annual healthcare expenditures in the United States attributable to hospital-acquired AKI exceed $10 billion (Susantitaphong et al., 2013; Uchino, 2010; Waikar et al., 2008). Therefore, AKI is expensive and complicated. As AKI management requires the full support of kidney functions, the therapy of choice for managing AKI in critically ill patients is continuous renal replacement therapy (CRRT) (Baldwin & Fealy, 2009; Bellomo, Kellum, & Ronco, 2012; Uchino, 2010).

CRRT is an extracorporeal blood purification therapy designed to mimic normal renal function over an extended period (Baldwin & Fealy, 2009; Bellomo et al., 2012; Uchino, 2010). Clinical trials have demonstrated the beneficial effects of CRRT compared to intermittent hemodialysis (IHD) on hemodynamic stability, solute clearance, and ultrafiltration capacity (Augustine, Sandy, Seifert, & Paganini, 2004; Bellomo et al., 2012; Dirkes & Wonnacott, 2016). As a result, CRRT use has increased dramatically in the past decade (Lameire et al., 2013; Susantitaphong et al., 2013; Uchino, 2010; Waikar et al., 2008). Management of CRRT has

consequently become a core competency in critical care nursing, requiring ICU nurses to have the knowledge and skills necessary to provide safe and effective CRRT care (Baldwin & Fealy, 2009; Bellomo et al., 2012).

A nurse's job performance is defined as the level of effectiveness a nurse has in carrying out his or her roles and responsibilities related to direct nursing care and the quality of healthcare services (Schwirian, 1978), and studies have demonstrated the link between nursing performance and quality of care (Kurtzman, Dawson, & Johnson, 2008; Needleman, Kurtzman, & Kizer, 2007). Intensive care unit (ICU) nurses face challenges when performing their roles in managing CRRT because patients receiving this therapy represent a diverse population with high illness severity and multiple organ failure (Baldwin & Fealy, 2009; Bellomo et al., 2012). In addition, CRRT is a complex multidimensional process requiring that ICU nurses master relevant technical skills and have substantial base knowledge about AKI, CRRT, and multiple diagnoses (Baldwin & Fealy, 2009). Furthermore, CRRT is a low-frequency procedure, making it a challenge for ICU nurses to maintain competency (Przybyl, Evans, Haley, Bisek, & Beck, 2017; Schell-Chaple, 2017). For example, at the Oregon Health and Science University Hospital (OHSU), an academic medical center, an ICU nurse might only manage CRRT once or twice annually, potentially resulting in feelings of ill-preparedness and low self-confidence (OHSU, 2013). Managing CRRT requires the ICU nurse to provide an ongoing assessment of the patient and machine in addition to managing other critical tasks and therapies, such as mechanical ventilation and medication infusions, resulting in an increased workload (Baldwin & Fealy, 2009; Schell-Chaple, 2017). Finally, the current literature reveals that CRRT nursing training programs are not standardized across settings, with training program lengths varying between one to three days (Baldwin & Fealy, 2009; Mottes et al., 2013; Schell-Chaple, 2017), and

although class sizes currently range from between five to twelve nurses, the optimal class size for ensuring proper training is unknown (Mottes et al., 2013). Moreover, despite the myriad of challenges related to developing CRRT competency, there is no standard approach to CRRT training nationally or internationally (Langford, Slivar, Tucker, & Bourbonnais, 2008; Mottes et al., 2013), and importantly, little is known about how to optimally support nurses who manage CRRT in the ICU to maintain their competency level.

The ICU environment is considered a demanding and stressful setting in which ICU nurses must continuously and quickly respond to the critical needs of their patients and the patients' families, perform procedures accurately, and coordinate care with other healthcare providers (Gurses & Carayon, 2007; Gurses, Carayon, & Wall, 2009). Consequently, patient safety and quality of care can present significant problems in the ICU (Gurses & Carayon, 2007, 2009; Gurses et al., 2009). Research has demonstrated that characteristics of the ICU environment can create obstacles for ICU nurses in performing patient care tasks, which can affect the quality and safety of their work (Gurses & Carayon, 2007, 2009; Gurses et al., 2009; Sarudi, 2001; Institute of Medicine, 2004). For example, frequent interruptions, an increased workload, lack of information, equipment malfunction, ineffective inter-provider communication, and high noise levels can lead to medical errors, care delivery delay, and subpar performance (Gurses & Carayon, 2007; Institute of Medicine, 2004).

Although several studies have examined the ICU work environment, many lack detailed descriptions of the factors affecting ICU nursing practice and quality of care (Gurses & Carayon, 2007, 2008; Gurses et al., 2009). It is generally known that factors related to elements of the ICU work environment, such as teamwork and collaboration, coordination, communication, task complexity, workload, and noise, can influence performance, quality of care, and patient safety (

Gurses & Carayon, 2007, 2008; Gurses et al., 2009). However, there is currently no detailed description of factors that impact ICU nursing practices and quality of care, the way these factors influence each other, and their effects on CRRT practice. To our knowledge, no prior study has systematically and comprehensively described the factors in ICU work environments that influence CRRT management, ICU nurses' performance, quality of care, and patient safety.

Importantly, the challenges facing ICU nurses when managing CRRT and the unique nature of the ICU environment can impact the quality and safety of CRRT practice. The work system model (Smith & Carayon, 1989) was used to guide the present study to better understand the relationship between ICU nurses' performances, the ICU environment, CRRT practice, and quality and safety of care. Smith and Carayon (1989) developed this model to describe elements of work that affect worker and patient outcomes.

According to the work system model, a *person* performs a range of *tasks* using various *tools and technologies*. The performance of these tasks occurs within a certain *physical environment* and under specific *organizational conditions*. Hence, the elements of a work system are 1) the person, 2) tasks, 3) tools and technologies, 4) physical environment, and 5) organizational conditions. These five elements interact with and influence each other. Interactions among various elements produce different outcomes in terms of performance, safety and quality of care, and working life (job satisfaction, stress, safety, and worker health and well-being) (Carayon et al., 2006; Carayon, 2009; Carayon & Smith, 2000). Although the present study used the model as a sensitizing framework to support describing and identifying factors that influence CRRT practice as experienced by ICU nurses, the model was not used as a "cookbook." No attempt was made to fit data to the model, and the I explored other elements as they emerged from the data.

Significance to Nursing

One in five critically ill adults experiences AKI during a hospital stay (US Renal Data System, 2018). Changes in renal function, disease complexity, and an advanced patient age make AKI a challenging condition for ICU nurses and other practitioners to manage. CRRT has become the therapy of choice when managing critically ill patients with AKI because it gently removes fluid, does not cause rapid shifts in fluid and electrolytes, and is associated with reduced dialysis dependence post-ICU discharge (Augustine et al., 2004; Bellomo et al., 2012; Dirkes & Wonnacott, 2016). ICU nurses are primarily responsible for administering CRRT therapy and thus initiate therapy, regularly monitor patients and machines, troubleshoot alarms, and take down therapy (Baldwin & Fealy, 2009; Schell-Chaple, 2017). During CRRT, continuously assessing and monitoring the patient and machine are critical for preventing complications associated with fluid and electrolyte imbalance, blood and heat loss, infection, and poor filtration.

This study is significant for two reasons. First, ICU nurses' perceptions of CRRT management in the ICU are documented and reflect the perspectives of those at the forefront of CRRT care. Second, although CRRT nursing research has focused on the implementation of CRRT therapy in the ICU and the question of who should manage CRRT in the ICU (i.e., nephrology nurses or ICU nurses), factors influencing the performance, safety, and quality of CRRT practice in the ICU have not previously been investigated. This study systematically describes and identifies performance obstacles in the ICU to enable a better understanding of CRRT nursing practice and increase awareness of the influence of the ICU work environment on CRRT practice. This work also has the potential to facilitate the development of targeted interventions that promote safe and effective CRRT practice. By establishing a foundation

regarding the impact of the ICU work environment on CRRT practice, this study paves the way for future research focusing on the impact of CRRT practice on patient outcomes (e.g., shorter ICU stays, fewer adverse events, and shorter therapy durations).

Knowledge about the impact of the ICU work environment on the performance of ICU nurses when managing CRRT may be helpful in improving CRRT practice and quality of care. A small body of research has investigated the impact of performance obstacles in the ICU work environment on ICU nurses' workloads and perceived quality and safety of care (Gurses & Carayon, 2007, 2008; Gurses et al., 2009). However, the available research has primarily relied on interviews, observations, and descriptive data collection methods such as surveys. In addition, no specific instruments measuring the effect of the ICU work environment on CRRT practice had undergone psychometric evaluation prior to this study. Considering the complexity of the ICU environment and the highly technical and demanding CRRT procedure, there is an increasing need for a reliable and valid instrument *applicable* to CRRT practice that can accurately *quantify* the impact of the ICU work environment on CRRT management.

Purpose of the Study

The purpose of this sequential exploratory mixed methods study was to identify and describe factors in the ICU work environment perceived to influence the performance of ICU nurses and affect CRRT practice in the ICU, and to develop a CRRT-specific instrument to measure the impact of the ICU work environment on CRRT practice. This research had two phases: a qualitative phase followed by a quantitative phase. The first phase was a dimensional analysis (DA) grounded theory study examining ICU nurses' perceptions of the effect of the ICU work environment on CRRT practice, quality of care, and patient safety. A purposeful sample of ICU nurses from three adult ICUs, at an urban academic hospital, was recruited for this research

phase. Data were gathered through semi-structured interviews regarding factors related to elements of the ICU work environment, such as ICU nurses' characteristics, CRRT management tasks, CRRT machines, ICU physical environment, training and preparation, and organizational conditions. Data were analyzed to develop a grounded theory that describes 1) dimensions of the ICU work environment that affect ICU nurses' performance and CRRT practice and 2) interaction patterns among factors in the ICU work environment and their perceived influence on ICU nurses' performance, quality of care, and patient safety.

In the second phase, concepts developed from the grounded theory were incorporated and transformed into instrument items, variables, and subscales to measure the perceived impact of the ICU work environment on CRRT practice, ICU nurses' performance, quality of care, and patient safety. The developed instrument was pilot tested and subsequently distributed to a national sample of ICU nurses to establish its psychometric properties. The combination of qualitative and quantitative approaches in this research offered an opportunity to examine the phenomenon in different ways while providing a foundation for the development of an instrument grounded in ICU nurses' experiences with CRRT management that has good psychometric properties.

Research Questions

The main research questions for this study were:

1- What factors do ICU nurses perceive impact their performance, quality of care, and patient safety when managing CRRT in the ICU?
2- What is the impact of the ICU work environment on CRRT practice, ICU nurses' performance, quality of care, and patient safety?

The subsequent questions for each phase were as follows:

Qualitative phase:

- How do ICU nurses describe the ICU work environment in relation to CRRT practice?
- What are ICU nurses' perceptions about the support and preparation needed to safely and effectively manage CRRT in the ICU?

Quantitative phase:

- What factors do ICU nurses identify in the ICU work environment that impact CRRT nursing care?

Specific Aims

The specific aims of this study were as follows:

Aim 1: describe the impact of the ICU work environment on CRRT nursing practice, ICU nurses’ performance, quality of care, and patient safety

Aim 2: identify ICU nurses’ perceptions of factors in the ICU work environment that influence their performance when managing CRRT and quality and safety outcomes

Aim 3: generate a substantive grounded theory of the ICU work environment and CRRT nursing practice

Aim 4: develop and test an instrument to measure the perceived impact of the ICU work environment on CRRT nursing practice, quality of care, patient safety.

Findings from this study are intended to offer information that can be used to improve support for nurses’ CRRT practice and provide a basis for the development of much-needed,

targeted interventions for improving patient safety and quality of care delivery for this increasingly utilized and technically complex therapy. Finally, the study results provide a basis for future work developing quality and safety measures and interventions to improve patient outcomes after receiving CRRT.

CHAPTER TWO

Literature Review

Continuous renal replacement therapy (CRRT), an extracorporeal blood purification therapy, is increasingly being used in ICU settings to support renal function in critically ill patients with acute kidney injury (AKI). This therapy cleans blood toxins, removes excessive fluid, and corrects acid-base imbalance. ICU nurses face challenges when managing CRRT, and the unique nature of the ICU environment can affect the performance of ICU nurses and the quality and safety of CRRT practice. The purpose of this literature review is to provide an understanding of what is known and not known about CRRT practice and the impact of the ICU environment on ICU nurses' performance when managing CRRT, quality of care, and patient safety. Identifying gaps in existing knowledge also helps explain and support the need for this study.

This chapter first reviews the literature on AKI prevalence and the complexity of this disease, CRRT, and CRRT practice, including historical background, definitions, complications, nurses' responsibilities, and training and competency. Then, the review focuses on the ICU work environment and its impact on practice, ICU nurses' performance, quality of care, and patient safety.

Acute Kidney Injury (AKI): A Common and Complex Condition

Definition of AKI

Acute kidney injury, formerly called *acute renal failure* (ARF), is commonly defined as an abrupt decline in renal function. AKI is clinically manifested as a reversible, acute increase in blood urea nitrogen (BUN) and serum creatinine (SCr) levels over the course of hours to weeks (Bellomo, 2005; Joslin et al., 2015; Mehta et al., 2007; Roy et al., 2013; Warnock, 2005).

Historically, there has been substantial variation in AKI definitions. For instance, studies have described AKI based on SCr changes, absolute levels of SCr, changes in BUN or urine output, or the need for dialysis (Bagshaw, George, Dinu, & Bellomo, 2007; Bellomo et al., 2012; Mehta et al., 2004; Uchino, Bellomo, Goldsmith, Bates, & Ronco, 2006). This variation in AKI definitions has made it difficult to compare information across studies and populations (Bagshaw, George, & Bellomo, 2008; Bellomo et al., 2012; Mehta et al., 2004), and several classification systems have been developed in an attempt to unify definitions and standardize clinical practice (Lopes & Jorge, 2013; Mehta et al., 2007; Warnock, 2005).

In 2002, the Acute Dialysis Quality Initiative (ADQI) was created with the primary goal of developing consensus and evidence-based guidelines for the treatment and prevention of AKI (Lopes & Jorge, 2013; Mehta et al., 2007; Warnock, 2005). The first order of business was to create a uniform, accepted definition of AKI; hence, the "RIFLE criteria" were established (Bellomo, Kellum, & Ronco, 2004; Bellomo et al., 2012). The RIFLE classification defines three grades of AKI severity based on changes in SCr and urine output (**R**isk, **I**njury, and **F**ailure) and two clinical outcomes (**L**oss and **E**nd-stage) (Bagshaw et al., 2008, 2007; Cruz, Ricci, & Ronco, 2009) (see Figure 2.1 for definitions of these grades). This criteria-based definition has been clinically applied across different ICU settings. The RIFLE criteria consider creatinine changes from baseline, help distinguish between mild or severe disease, and have demonstrated sensitivity and specificity within different populations (Bellomo et al., 2004; Deepa & Muralidhar, 2012; Roy et al., 2013; Uchino et al., 2006).

Several studies have validated the RIFLE criteria and applied the definition in clinical practice. For example, the RIFLE criteria were used to predict mortality in ICU patients with AKI who had received CRRT (Abosaif, Tolba, Heap, Russell, & Nahas, 2005; Bell et al., 2004;

Uchino, 2010). These studies found that classification into the "F" grade was associated with an increase in mortality compared with patients assigned to "R" or "I" grades (Abosaif et al., 2005; Bell et al., 2004; Uchino, 2010). In addition to its predictability, the RIFLE system was found to be clinically relevant and internally consistent (Abosaif et al., 2005; Bagshaw et al., 2008, 2007; Deepa & Muralidhar, 2012).

In 2004, the RIFLE criteria were refined by the Acute Kidney Injury Network (AKIN), an international collaboration of nephrologists and intensivists, and a new classification system called *AKIN* was developed. The AKIN group recommended that the term AKI be used to represent the full spectrum of renal injury, from mild to severe, with the latter meaning an increased likelihood of unfavorable outcomes such as loss of function and end-stage renal disease (ESRD) (Bagshaw et al., 2008; Mehta et al., 2007). The AKIN group's goal was to increase the sensitivity of the RIFLE criteria by recommending that a smaller change in SCr (≥ 26.2 μmol/L) be used as the threshold for defining the presence of AKI and identifying patients with Stage 1 AKI—analogous to RIFLE-Risk. The group also proposed a time constraint of 48 hours for the diagnosis of AKI compared to the RIFLE criterion of one to seven days. Finally, the AKIN classifies any patients receiving renal replacement therapy (RRT) as Stage 3 AKI (RIFLE-Failure) (Figure 2.1). However, it was subsequently demonstrated that the AKIN criteria did not, to any great degree compared to the RIFLE criteria, improve the sensitivity, robustness, or predictive ability of the definition and classification of AKI in the first 24 hours after patient admission to the ICU (Bagshaw, Berthiaume, Delaney, & Bellomo, 2008; Cruz et al., 2009; Lopes & Jorge, 2013). Both criteria may essentially provide the same information, and therefore, the consolidation of both criteria into an agreed-upon definition that can be easily and uniformly applied nationally and internationally is recommended.

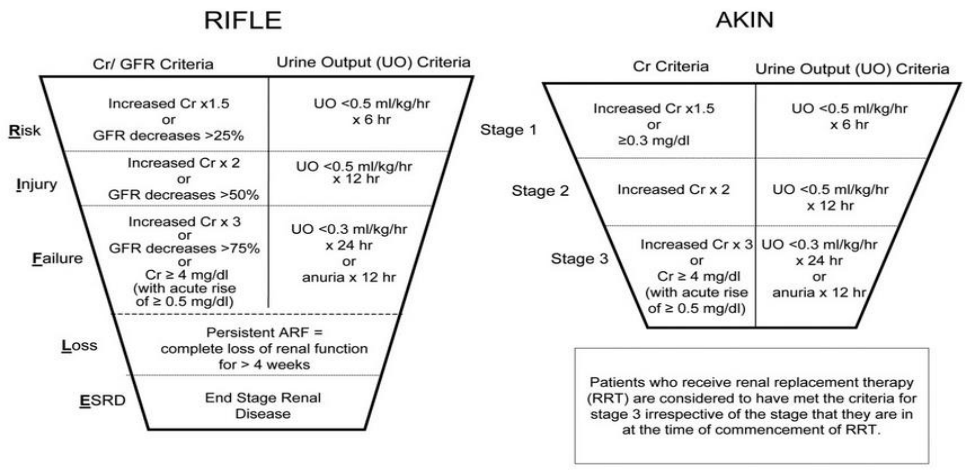

Figure 2.1. RIFLE and AKIN classifications for AKI. RIFLE stands for Risk, Injury, Failure, -Loss, End-stage. AKIN stands for Acute Kidney Injury Network. RF = renal failure; Cr = creatinine; GFR = glomerular filtration rate. Adapted from "Clinical review: RIFLE and AKIN–time for reappraisal," by D. Cruz, Z. Ricci, and C. Ronco, 2009, *Critical Care, 13*, p. 21. Copyright 2009 by BioMed Central Ltd.

AKI Prevalence Rate and Statistics

In 2016, for Medicare patients aged 66 years and older, the incidence rate of AKI in blacks in this age group was 71.6 per 1,000 patients per year; compared to 44.7 and 35.8 in whites and individuals of other races, respectively. Of note, rates of AKI rose across all race subgroups between 2006 and 2016 (US Renal Data System, 2018). Rates of AKI were also strongly influenced by age. In 2016, the rate of AKI for those aged 66-69 year was 23.0 per 1,000 patients per year, which has increased to 31.3, 44.2, 62.9, and 95.7 for those aged 70-74, 75-79, 80-84, and 85 years and older, respectively (US Renal Data System, 2018). In addition to race and advanced age, other risk factors for developing AKI are diabetes mellitus, heart failure, liver failure, chronic kidney disease, hypotension, and sepsis. Patients who undergo cardiac/vascular surgery, organ transplantation, or mechanical ventilation or who are exposed to

contrast media, nonsteroidal-Anti-inflammatory drugs (NSAIDs), antimicrobial drugs, or chemotherapeutic agents commonly experience AKI as a complicating condition (Brown, Rezaee, Marshall, & Matheny, 2016; Kellum, Bellomo, & Ronco, 2009). Therefore, patients who require CRRT to support their kidney function tend to be older, sicker, and with multiple diagnoses.

The American Society of Nephrology (ASN) (2016) has estimated that 20 million Americans are at increased risk for developing AKI, which is diagnosed in more than 300,000 Americans each year (ASN, 2016). Other risk factors for developing AKI, as defined by RIFLE criteria, are sepsis, greater severity of illness as per the Acute Physiology and Chronic Health Evaluation (APACHE) III or Sepsis-related Organ Failure Assessment (SOFA) scores, preexisting chronic kidney disease, preceding admission to a non-ICU ward in a hospital, surgical patients, and being on mechanical ventilation (Bellomo et al., 2012). AKI is characterized by a sudden deterioration in renal excretory function, accumulation of products of nitrogen metabolism such as creatinine and urea, and increased concentrations of potassium and phosphate (Carl et al., 2010; Lameire et al., 2013; Silver & Chertow, 2017; Susantitaphong et al., 2013). Note that an increase in SCr is associated with an increase in mortality (Clark et al., 2017; Waikar et al., 2008). Specifically, an SCr $\geq$ 0.5 mg/dl is associated with a 6.5-fold increase in the chance of death, a 3.5 day increase in the length of stay (LOS), and nearly $7,500 in excess hospital costs across multiple diagnoses (Chertow, 2005; Palevsky et al., 2013; Waikar et al., 2008). Overall, AKI is associated with increased death rates, increased healthcare costs, and may accelerate progression to ESRD (ASN, 2016; Joslin et al., 2015; Susantitaphong et al., 2013).

The high mortality rates associated with AKI may be due, at least in part, to advanced patient age and disease complexity (Dirkes & Wonnacott, 2016; Uchino, 2010; Waikar et al.,

2008). Older Americans are at a higher risk of developing AKI, and the rate of AKI in older American is expected to increase significantly (ASN, 2016). A 2011 Medicare report indicated a gradual increase in the incidence rate of AKI among older patients; AKI rates per 1,000 patients per year were 13.6, 18.1, 24.9, 34.2, and 46.9 in the age groups 66–69, 70–74, 75–79, 80–84, and 85 year and above, respectively (US Renal Data System, 2018). Furthermore, increased AKI mortality is associated with the presence of heart disease, cancer, sepsis, and neurological or hematological disorders (Tsagalis, 2011). AKI is considered a common complication across multiple diagnoses, and changes in renal function, disease complexity, and advanced age make AKI a challenging condition for ICU nurses and other practitioners to manage.

Continuous renal replacement therapy (CRRT): A Multidimensional and Complex Process

The Idea of CRRT

CRRT is an extracorporeal process in which blood is removed from the patient via the arterial lumen of a catheter, which is typically placed in the femoral, internal jugular, or subclavian vein, using a peristaltic blood pump and pushed through a semipermeable membrane before being pumped back into the patient via the catheter's venous lumen (Baldwin & Fealy, 2009; Bellomo et al., 2012; Clark et al., 2017; Uchino, 2010). When the blood passes through the membrane (hemofilter), electrolytes and small- and medium-sized waste are removed by convection and diffusion (Figure 2.2). Fluid removal is achieved by ultrafiltration at an established hourly rate and on a continuous basis. CRRT is usually performed continuously for 24–72 hours (Baldwin & Fealy, 2009; Bellomo et al., 2012; Clark et al., 2017; Uchino, 2010).

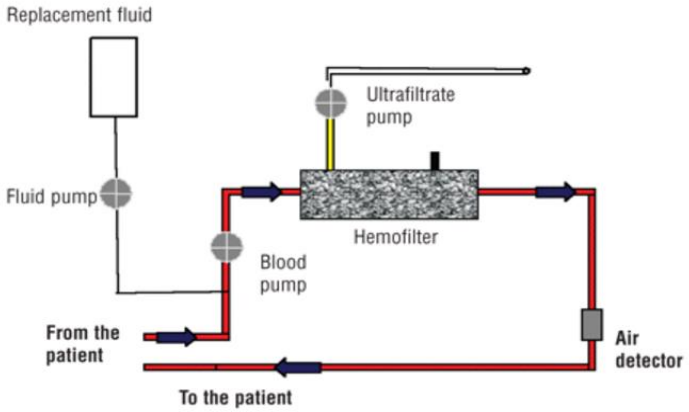

Figure 2.2. A continuous venovenous hemofiltration system. Adapted from "Continuous renal replacement therapy in the adult intensive care unit: History and current trends," by S. Dirkes and K. Hodge, 2007, *Critical Care Nurse, 27*(2), p. 63. Copyright 2007 by The American Association of Critical-Care Nurses.

Before CRRT was developed, two RRT modalities were used to manage AKI: intermittent hemodialysis (IHD) and peritoneal dialysis (PD). The latter uses the peritoneum as a natural semipermeable membrane for diffusive removal (i.e., moving solutes from an area of high concentration to an area of low concentration across a semipermeable membrane) of solutes such as potassium, phosphorus, and urea (Ansari, 2011). PD is a highly effective treatment modality in patients with chronic renal failure, and patient outcomes are at least equivalent to those treated with IHD (Ansari, 2011; Uchino, 2010). IHD involves the diffusive removal of solutes and ultrafiltration (UF) techniques (i.e., the removal of water from blood due to a pressure gradient across a semipermeable membrane). The total amount of solute transported per unit of time (clearance) in IHD depends on the molecular weight of the molecule, membrane characteristics (dialyzer), dialysate flow, and blood flow. In general, IHD is prescribed for three to six hours per treatment session (Uchino, 2010).

The idea of CRRT for critically ill patients was first proposed in the 1960s because IHD was not well tolerated by these patients due to hemodynamic instability (Dirkes & Wonnacott, 2016; Kellum et al., 2009), and PD was contraindicated in patients with abdominal wounds (Price, 1992) and less effective in hypercatabolic, poisoning, and pulmonary edema cases (Alarabi, Danielson, Wikström, & Wahlberg, 1989; Ansari, 2011; Passadakis & Oreopoulos, 2001). Moreover, only small molecular weight solutes can be removed using PD and IHD (Burchardi, 1999). As a result, new membranes for renal replacement techniques were developed in 1966. These filters were characterized by high filtration rates with solutes up to a certain molecular weight were filtered by convection—the movement of solvent (fluid) across a semipermeable membrane and the drag of solutes from an area of high pressure to an area of low pressure (Burchardi, 1999). In 1967, Henderson played a crucial role in developing the technical groundwork for hemofiltration by describing the process of removing toxins from blood by the convective transport mechanism (Henderson, Besarab, Michaels, & Bluemle, 2004). Burton assigned the term "hemofiltration" in 1976 to this new convective technique, and the first multicenter trial was initiated to evaluate its effectiveness for treating chronic renal failure (Burchardi, 1999; Henderson et al., 2004). A year later, Kramer developed the continuous arteriovenous hemofiltration (CAVHF) technique, which exploits a systemic arteriovenous pressure difference in an extracorporeal circuit to continuously produce an ultrafiltrate (Burchardi, 1999). The advantages of this effective method for eliminating fluid and solutes are its technical simplicity—no blood pump is needed, and the hemodynamic stability of critically ill patients. Therefore, CAVHF soon became a widely used method for treating ARF in intensive care patients, and IHD and PD become less frequently used. However, the limited capacity of CAVHF to remove nephrotoxins in the presence of high catabolism such as uncontrolled

azotemia (Jenkins, 2007) and complications related to arterial access such as hemorrhage, infection, arteriovenous fistula, and pseudoaneurysm (Tominaya, Ingegno, Geraldi, & Waxman, 1992), led to the development of a venovenous pump-driven technique achieving independence from systemic circulation and arterial access. Further progress to improve solute clearance was made by combining the convective principle of hemofiltration (CVVH) with the diffusive transport of dialysis (CVVHD) to create continuous venovenous hemodiafiltration (CVVHDF). Today, this combination is the most effective renal replacement technique for treating ARF in critically ill patients (Kellum et al., 2009; Ronco, 2017; Ronco, Davenport, & Gura, 2008).

CRRT has become the therapy of choice , over IHD, in the management of critically ill patients with AKI because unlike IHD, CRRT gently removes fluid, does not cause a rapid shift in fluid and electrolytes, and is associated with less dialysis dependence after ICU discharge (Baldwin & Fealy, 2009; Bellomo et al., 2012; Chertow, 2005; Schneider & Bellomo, 2013; Uchino, 2010). However, there is inconsistency in the literature regarding the superiority of CRRT over IHD. Four systematic reviews and four meta-analyses examining the modality of renal support in AKI have been published in the past 10 years, and all have reported no differences in patient mortality or recovery of kidney function across modalities (Bagshaw et al., 2008; Rabindranath, Muirhead, & MacLeod, 2006; Schneider & Bellomo, 2013; Susantitaphong et al., 2013). Some studies, however, have suggested that the cost of CRRT is higher than that of IHD (Pannu et al., 2008). In the ICU, CRRT costs approximately $3,629.80 per day per patient more than does IHD. The four main determinants of cost are nurse staffing, replacement and dialysis fluid, anticoagulation agents, and the extracorporeal circuit (Chertow, 2005; Srisawat, Lawsin, Uchino, Bellomo, & Kellum, 2010).

In conclusion, CRRT has evolved over the years, and different modalities have been used to support renal function in AKI. Despite the divergence of evidence related to the superiority of AKI therapy modalities, CRRT is considered the therapy of choice for critically ill patients with AKI due to its capacity to gently remove fluid, correct acid-base imbalance, and attain negative fluid balance therapy goals.

ICU Nurse Responsibilities

ICU nurses are primarily responsible for administering CRRT therapy. These nurses initiate therapy, perform hourly monitoring of the patient and machine, troubleshoot alarms, and terminate therapy (Baldwin & Fealy, 2009; Dirkes & Wonnacott, 2016; Schell-Chaple, 2017). Continuous assessment and monitoring of the patient and the machine during CRRT are essential for preventing complications associated with fluid and electrolyte imbalance, blood and heat loss, infection, and poor filtration.

Close monitoring of the patient and the machine during CRRT is also critical. ICU nurses must closely monitor the patient's fluid volume, laboratory values (i.e., electrolyte levels, acid-base status, blood components), fluid removal goals, anticoagulation therapy, venous catheter site and function, and hemodynamic status (Cruz et al., 2010; Liu et al., 2014; Schneider et al., 2013). The CRRT system requires constant monitoring for patency, alarm conditions, flow rates of dialysate and replacement solutions, blood flow rates, and anticoagulation agent doses and side effects. Unfortunately, there is no consensus regarding what constitutes best practice when monitoring patients and machines during CRRT. For example, there is variation in how ICU nurses document fluid balance. One study has recommended charting fluid intake and output through CRRT on a separate form (Martin & Jurschak, 2007), while another study has advised that all fluid intake and output, including those from CRRT, should be charted on one form

(Ronco, Ricci, Bellomo, Baldwin, & Kellum, 2005). Despite expert nursing knowledge and fluid documentation approaches, fluid balance calculations remain a potential source of error in CRRT management, and this facet of care demands accuracy (Augustine et al., 2004; Bouchard & Mehta, 2009; Bourbonnais, Slivar, & Tucker, 2016; Mehta, 2001; Ronco et al., 2005; Ronco, 2005). Unfortunately, hypovolemia due to errors in fluid calculation are still reported (Bouchard & Mehta, 2009; Ronco et al., 2005; Ronco, 2005). Failure to properly and accurately assess fluid, as well as electrolytes and the acid-base status, leads to errors, patient harm, and death unless clear recommendations, based on strong evidence, are implemented to guide CRRT nursing practice.

ICU nurses are required to maintain CRRT progress by minimizing therapy down-time, which is defined as the number of hours spent off filter (i.e., not receiving CRRT) (Baldwin, 2007). At present, however, little is known about the relationship between the amount of CRRT down-time each day and the worsening of AKI (Baldwin & Bellomo, 2004; Baldwin, 2007; Dirkes & Wonnacott, 2016; Uchino, 2010). A prospective study of ten ICU patients reported that >20% of potential CRRT operational time was wasted due to therapy interruptions and frequent clotting of the filter (Baldwin, 2007). CRRT down-time is also associated with the loss of uremic control (Kleger & FäSsler, 2010). The longer the down-time, the less effective the treatment (Baldwin, 2007; Kleger & FäSsler, 2010), which may subsequently lead to increases in CRRT duration and cost. Therefore, maintaining function of the extracorporeal filter is important for effective waste clearance and excess fluid removal and requires close monitoring. More research is needed to gain insight into how current practice effects circuit function to optimize therapy effectiveness and minimize patient harm.

ICU nurses perceive CRRT as being technically complex and requiring special knowledge and skills for safe and effective delivery of care. However, there is a critical gap in the knowledge concerning how to optimally support nurses who deliver this multidimensional and complex therapy.

CRRT: Training and Competency

Optimal CRRT delivery relies on expert bedside nursing staff to maintain the prescribed therapy, troubleshoot technical issues, and ensure patient safety. Therefore, ICU nurses need specialized knowledge and skills to manage these added responsibilities (Baldwin & Fealy, 2009; Kleger & FäSsler, 2010; Mottes et al., 2013; Schell-Chaple, 2017; Uchino, 2010). Generally, it has been suggested that increased educational requirements and supported training improve patient care quality (Kleger & FäSsler, 2010; Kocjan & Brunet, 2010; Langford et al., 2008; Mottes et al., 2013). Unfortunately, no clear determination of the educational requirements for nurses managing CRRT is available, and training approaches are not standardized (Baldwin & Fealy, 2009; Graham & Lischer, 2011; Przybyl et al., 2017). In 2011, the American Association of Critical-Care Nurses (AACN) endorsed the *Standards of Practice and Guidelines of Care for CRRT*, published by the American Nephrology Nurses' Association. However, specific guidelines regarding staff training are not provided in that publication (Mottes et al., 2013). Thus, institutions have had to define their own educational policies, such as by setting nursing qualifications for CRRT training; determining the format, duration, and setting of CRRT training; and monitoring nurses' CRRT competency. Consequently, there are no universal competencies for CRRT, and researchers' understanding of how to best support the competency of ICU nurses in terms of CRRT remains limited (Baldwin & Fealy, 2009; Golestaneh, Richter, & Amato-Hayes, 2012; Graham & Lischer, 2011; Langford et al., 2008; Przybyl et al., 2017).

Despite proposing that ICU nurses' knowledge and skill levels may affect patient safety and treatment quality, researchers have not examined the training and competency level necessary to optimally support CRRT practice. Therefore, an assessment is required regarding ICU nurses' perceptions of CRRT practice in the ICU environment and how their preparation optimally supports their delivery of safe and quality care.

The ICU Work Environment

The ICU environment is considered demanding and stressful; ICU nurses must continuously and quickly respond to the critical needs of patients and their families, accurately perform procedures, and coordinate care with other healthcare providers (Gurses & Carayon, 2007; Gurses et al., 2009; Reis Miranda & Jegers, 2012). Consequently, patient safety and quality of care can be major issues in the ICU (Gurses & Carayon, 2007; Gurses et al., 2009) Previous research has demonstrated that characteristics of the ICU environment create obstacles for ICU nurses performing patient care tasks that can negatively impact the quality and safety of their work (Gurses & Carayon, 2007; Gurses et al., 2009; Institute of Medicine, 2004). Performance obstacles can originate from five elements in the work system: persons, tasks, tools and technologies, the physical environment, and the organization (Carayon et al., 2006; Carayon & Smith, 2000).

The Balance Theory, the Work System Model, and the Systems Engineering Initiative for Patient Safety (SEIPS) Model of Work System and Patient Safety

After reviewing and critiquing various bodies of literature addressing job design and the impact of work on the well-being and performance of individuals, Smith and Carayon (1989) developed the balance theory of job design for stress reduction. This theory was created in an attempt to develop a more realistic and holistic approach to identifying *elements of the work*

system that produce *stress loads (psychosocial, cognitive, and physical loads)*, which then lead to various *outcomes* (Figure 2.3) (Carayon, 2009; Carayon & Smith, 2000; Smith & Carayon, 1989).

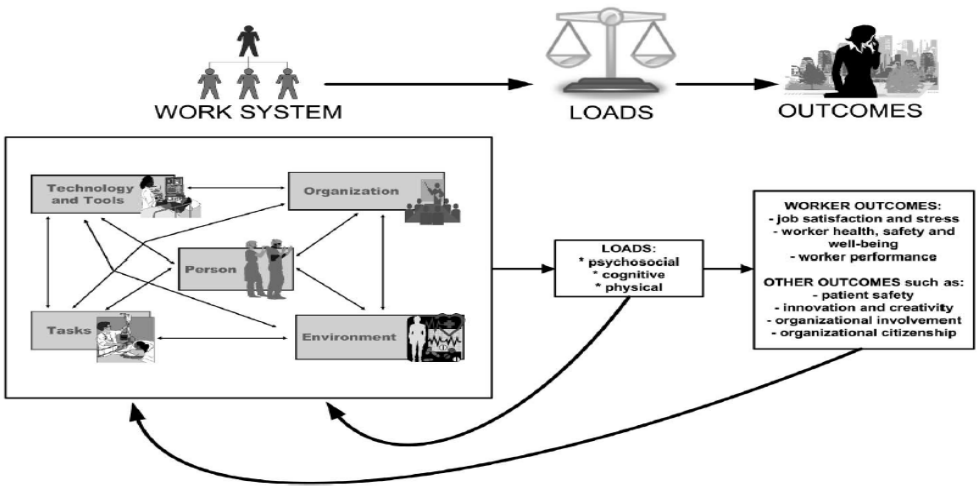

Figure 2.3. The balance theory: impact of the work system on psychosocial, cognitive, and physical loads and outcomes. Adapted from "The Balance Theory and the Work System Model … Twenty Years Later," by P. Carayon, 2009, *International Journal of Human-Computer Interaction, 25*(5), p. 318. Copyright 2009 by Taylor & Francis Group, LLC

The work system model, as a part of the balance theory, describes elements of work that affect workers and outcomes. According to the work system model, a *person* performs a range of *tasks* using various *tools and technologies*. The performance of these tasks occurs within a certain *physical environment* and under specific *organizational conditions*. Hence, the elements of a work system are as follows: 1) person, 2) tasks, 3) tools and technologies, 4) physical environment, and 5) organizational conditions (Figure 2.4). These five elements interact and

influence each other. Interactions among various elements produce different loads and outcomes (Carayon et al., 2006; Carayon & Smith, 2000; Carayon et al., 2014; Smith & Carayon, 1989).

An explanation of how the work system elements interact with each other is provided here. The person is at the center of the model. A person has characteristics that affect and can be affected by the work system's other elements. These characteristics include personality type, physical health status, skills and abilities, prior experiences, motivation, age, gender, and educational level. Tasks a person must perform may require certain knowledge, be repetitive in nature, or create an increase in workload. The ability to accomplish tasks may require technical knowledge and skills and a suitable environment. The person needs training and support to complete tasks and to safely and effectively use technology. Support and training come from the organization in the form of training activities and an accessible policies and procedures manual.

The work system elements can create psychosocial, cognitive, or physical loads, or a combination of all three, on a person. For instance, the tasks performed by a person have psychosocial dimensions such as control over work pace, cognitive dimensions such as information overload, and physical dimensions such as repetitiveness. These psychosocial, cognitive, and physical loads created by the work system elements interact. The person attempts to use available resources within the work system to manage these loads. Such resources are biological resources (energy expenditure, biomechanical strain, and physical status), psychological resources (perception, cognition, decision-making, and emotion), and behavioral resources (motivation and coping behaviors). When a load becomes too great to manage, the individual may exhibit stress responses or reactions (emotions, behaviors, and biological reactions), leading to maladaptation and a lack of performance. If an individual frequently experiences these reactions over a prolonged period, his or her health may be negatively affected,

for example, by fatigue, burnout, muscle pain, and sleep disorders. Persistence of these disorders is likely to lead to a reduction of the individual's available resources to manage loads and continue unless external resources are made available or the load is reduced (Carayon et al., 2006; Carayon & Smith, 2000; Smith & Carayon, 1989). On the other hand, the work system can also produce positive effects such as an increased motivation to provide high-quality care (Carayon, 2009, 2010).

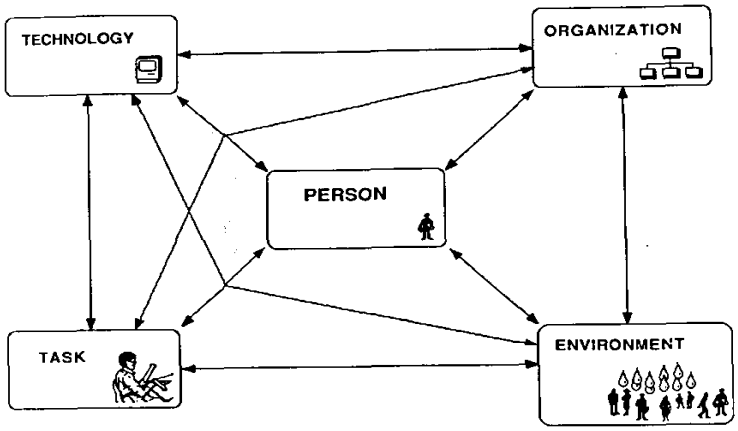

Figure 2.4. The work system model: interaction among work system elements. Adapted from "A balance theory of job design for stress reduction," by M. J. Smith and P. Carayon-Sainfort, 1989, *International Journal of Industrial Ergonomics, 4*(1), p 75. Copyright 2016 Elsevier.

As mentioned previously, the elements of the work system produce stress loads, which then lead to outcomes that can affect performance, safety, quality of care, and the quality of employees' working life through job satisfaction, stress, safety, and worker health and well-being (Carayon et al., 2006; Carayon, 2009; Carayon & Smith, 2000). Figure 2.3 illustrates that both loads and outcomes impact the work system elements, creating a loop effect. Hence, one must assess the work system elements and modify these factors to improve outcomes.

Carayon and colleagues at the University of Wisconsin developed the Systems Engineering Initiative for Patient Safety (SEIPS) model. The SEIPS model of work system and patient safety is a healthcare human factors model of person-centered socio-technical systems (Carayon, 2009; Holden et al., 2013). It assimilates the structure used by Donabedian (1988) in his structure-process-outcome (SPO) model of healthcare quality and the work system model (Smith & Carayon, 1989). The SEIPS model is considered complementary to and an extension of Donabedian's model (Carayon, 2009; Carayon et al., 2014; Holden et al., 2013).

Donabedian's model has been extensively used to examine clinical processes and outcomes of care. However, this model is limited in its recognition of the interactions and interdependencies among system components (structure). Donabedian's model explicitly and directly links the structure and processes of care to subsequent patient outcomes. The SEIPS model extends this idea by including feedback loops between outcome and structure, and process and structure. In Donabedian's model, structure consists of the organizational structure, which corresponds to the work system model component of organization; material resources, which correspond to the work system model components of environment and technology/tools); and human resources, which correspond to the work system model components of person and tasks). In Donabedian's model, quality is assessed by evaluating the processes of care—how provider tasks and clinical processes are both organized and performed—and evaluating the outcome(s) of care (i.e., assessing the clinical results and the impacts of and patient satisfaction with the care provided). The SEIPS model, on the other hand, assesses quality by evaluating the process of care and *other processes* that may occur in the work environment, such as maintenance, housekeeping, and supply chain management, and evaluating organizational and employee outcomes in addition to the patient's outcomes (Carayon, 2009; Carayon et al., 2014; Holden et

al., 2013). The SPO model focuses on providers and their relationship with the processes and outcomes, while the SEIPS model emphasizes the structure of the work environment and interactions among its elements (Carayon et al., 2006; Carayon, 2009; Carayon et al., 2014; Holden et al., 2013).

The SEIPS model has been further developed and few modifications were made to the original model (Figure 2.5). For example, the SEIPS 2.0 model includes an "external environment" variable, which incorporates macro-level societal, economic, ecological, and policy factors outside an organization, such as the national workforce, regulatory issues, and reimbursement. The process in the SEIPS 2.0 model was expanded to differentiate among work activities based on who is actively engaged in performing the tasks or duties. An active agent is the person performing some or all health-related work activity, including healthcare professionals, the patient, the patient's family, and community members. A "co-agent" is an indirect or passive contributor who is present in the process but relatively inactive. Thus, based on the degree of engagement in the performance process, the SEIPS 2.0 model categorizes processes into professional, patient, and collaborative work. Outcomes are comprehensively described by distinguishing proximal outcomes—the immediate result of work processes—and distal outcomes—results emerging over time. In addition, outcomes can be desirable or undesirable, and specific outcomes may reflect the goals of different stakeholders, such as clinicians, organizational leaders, regulators, payors, and, perhaps most importantly, patients (Holden et al., 2013). Finally, the concept of adaptation was added to the model, representing the idea that adaptations are made to decrease the gap between actual versus ideal performance. Adaptations can be anticipated or unanticipated, short- or long-lasting, and/or intermittent or regular.

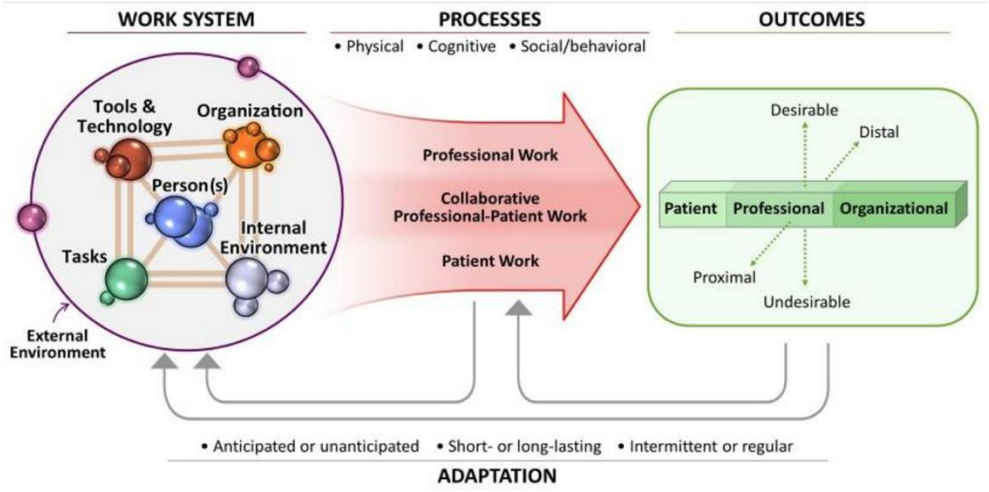

Figure 2.5. The Systems Engineering Initiative for Patient Safety (SEIPS) 2.0 model. Adapted from "SEIPS 2.0: A human factors framework for studying and improving the work of healthcare professionals and patients," by Holden et al., 2013, *Ergonomics, 56(11)*, p 23. Copyright 2013 Taylor & Francis.

The Impact of the ICU Working Environment

Several studies have examined the ICU work environment. However, these studies have failed to include detailed descriptions of factors affecting ICU nursing practice and quality of care (Gurses & Carayon, 2007, 2008; AGurses et al., 2009). That said, it is generally known that factors related to elements of the ICU work environment, such as teamwork and collaboration, coordination, communication, complexity of tasks and workload, and physical environment, can influence performance, patient safety, and quality of care (Gurses & Carayon, 2007, 2009; Gurses et al., 2009).

Teamwork. Poor teamwork and negative perceptions of team coordination in the ICU are associated with higher error rates (Donovan et al., 2018; Poncet et al., 2007; Reader, Flin, Mearns, & Cuthbertson, 2009). One study found that poor coordination—due to ICU nurses

being overloaded with requests, poor task delegation, and a lack of activity prioritization—results in more crisis management errors (Poncet et al., 2007). Similar to coordination, collaboration among healthcare providers has been found to be a factor affecting performance and quality of care (Miller, Scheinkestel, & Joseph, 2009; Pronovost, Wu, Dorman, & Morlock, 2002; Reader, Flin, Mearns, & Cuthbertson, 2007; Reader et al., 2009). Baggs and Schmitt (1995) have stated that higher levels of nurse-physician collaboration in decision-making about patient care are crucial for satisfaction among nurses. Furthermore, the level of collaboration during the decision-making process is influenced by the severity of a patient's condition (Baggs & Schmitt, 1995; Pronovost et al., 2002; Reader et al., 2009). In a less severe illness, decisions are made in a more democratic fashion with contributions from all team members (Baggs & Schmitt, 1995; Poncet et al., 2007; Pronovost et al., 2002; Reader et al., 2009). Nevertheless, regardless of the severity of a patient's condition, some senior nurses have reported feeling uninvolved in decision-making during ICU rounds (Poncet et al., 2007; Pronovost et al., 2002; Reader et al., 2009).

Issues with collaboration in healthcare have also been reported within disciplines such as collaboration among nurses, which has been identified as an indication of nursing ability. Increasing the level and quality of such collaboration has been associated with improvements in the work environment, patient safety, and quality of care (Apker, Propp, Zabava Ford, & Hofmeister, 2006; Liao, Qin, He, & Guo, 2015; Meretoja, Eriksson, & Leino-Kilpi, 2002). Moreover, inadequate collaboration among nurses has been identified as a primary contributor to medical errors, adverse events, operative and postoperative complications, and treatment delays (Liao et al., 2015). A study by Valiee, Peyrovi, and Nasrabadi (2014) reported a high prevalence of poor interactions, withholding of support, lack of coordination, tension, and intimidation

among nurses. Similar findings emerged in the 2005 AACN survey, which revealed that 53% of the ICU nurses in the sample reported withholding support from other nurses and 33% reported poor to fair interactions with peers (Alspach, 2009). Overall, improved collaboration and teamwork are associated with fewer medical errors, increased patient safety, and improved quality of care. There is a paucity of research on collaboration and teamwork during CRRT management, and thus, teamwork and collaboration among nurses and other professionals are needed to advance the science of CRRT management.

Communication. Improving communication in clinical areas is a national and international patient safety goal (Miller et al., 2009). Errors in the ICU increase after communication events (e.g., verbal or written instructions regarding routine care, shift change, and handover) with 37% of errors associated with nurse-physician communication (Reader et al., 2007). Provencio (2008) analyzed 2,075 web-based incident reports from 23 ICUs and revealed that recurrent team communication failures that led to patient harm were related to nurses' reluctance to report observed errors or patient care issues, a lack of communication about treatment changes between clinicians and nursing staff, inaccurate information transfer between different ICU teams, and poor communication regarding newly admitted patients. Moreover, team structure—specifically hierarchies—influenced perceptions of team communication openness (Provencio, 2008; Reader et al., 2007, 2009), and there was a difference between physicians' and nurses' perceptions of communication openness (Pronovost, 2002; Provencio, 2008; Reader et al., 2007, 2009). Of the nurses surveyed (n = 136), only one-third reported highly positive perceptions of communication openness with physicians (Reader et al., 2007). Furthermore, communication openness was associated with the degree to which team members reported understanding patient care goals (Pronovost, 2002; Provencio, 2008; Reader et al.,

2007, 2009). Nurse-nurse handover is another form of communication. Handover has been studied by focusing on the pragmatic methods of delivery with the assumption that these methods can be applied to any clinical setting with little consideration of the contextual variation, spatial location, and nurses' clinical experiences (Manias & Street, 2000). Therefore, the ICU communication related to CRRT must be examined in depth since no previous study has explored this aspect of CRRT practice.

Workload. Workload is one of the most important determinants of patient safety and quality of care in the ICU (Gurses & Carayon, 2007, 2009). Of note, a case study revealed that one ICU nurse caring for two patients during a 12-hour shift resulted in eight patient errors, with seven errors attributed to inadequate communication and collaboration (Henneman, 2008). High workloads and insufficient staffing levels were associated with drug administration and documentation problems, inadequate patient supervision, incorrect ventilator and equipment setup, and self-extubation incidents (Dougherty & Larson, 2010). Moreover, as the nurse-patient ratio decreased, postoperative pulmonary complications and resource use increased (Dougherty & Larson, 2010). A nurse-patient ratio of less than one-half was thus related to a 14% increase in direct hospital costs (Dougherty & Larson, 2010).

Adding CRRT to the care plan of a patient significantly increases the workload for ICU nurses. However, there are no clear guidelines on the proper nurse-patient ratio in this situation. To the author's knowledge, no past studies have examined the impact of CRRT on nurses' workloads, patient safety, and quality of care.

Physical environment. The ICU's physical environment affects patient safety and quality of care (Gurses & Carayon, 2007, 2009). For instance, factors in the ICU environment

that can create performance obstacles and safety issues include noise, workspaces, private patient room design, and supply room location. Moreover, environmental factors can facilitate device-use errors even with a well-trained, competent user (Johnson et al., 2007). High noise levels can mask alarms, low lighting can make displays hard to read, and the use of multiple devices at the same time can lead to confusion in ICU nurses (Johnson et al., 2007). Training or retraining users without due consideration of other salient factors—including the physical environment—may be ineffective in preventing device-use errors (Johnson et al., 2007).

Thus, the ICU work environment must be redesigned to reduce performance obstacles, improve patient safety, and increase quality of care (Gurses & Carayon, 2007, 2008). ICU organization, staffing ratios, staff training levels, and other factors in the ICU work environment may contribute to the survival rate of critically ill patients requiring CRRT (Kocjan & Brunet, 2010). However, since no research has examined the influence of the ICU work environment on CRRT practice, our understanding of the ICU work environment's impact on CRRT practice, ICU nurses' performance, quality of care, and patient safety is limited.

Nurses Performance and Work Environment Measurements

Nurse Performance Measurements

Quality of care and patient safety are priorities in healthcare, and the role of nurses in ensuring the quality and safety of ICU care has been clearly identified (Gurses & Carayon, 2009). Therefore, focusing on nurse staffing, nurses' impact on patient safety and healthcare outcomes, workplace practices, and standardization of care has led to an increased interest in measuring and reporting nurse performance (Aiken, Clarke, & Sloane, 2000; Needleman et al., 2007). Performance measures can be used to quantify the effect of nursing personnel on the structures, processes, and outcomes of care, and vice versa (Hertz, 2010; Kurtzman et al., 2008).

Needleman et al. (2007) have listed six purposes of measuring nurse performance: 1) quantifying nursing's influence on patient safety and healthcare outcomes; 2) enabling benchmarking and the sharing of best practices; 3) enhancing the clinical practice of nursing personnel and nursing-related quality improvement projects; 4) promoting provider accountability to the public; 5) identifying levels of staffing and approaches to organizing nursing in hospitals that can be implemented by hospitals and supported by payers and other public and private parties; and 6) identifying gaps in quality to inform the research, education, and training needed for measuring nursing-sensitive care.

The literature review revealed a paucity of measures to assess the performance of ICU nurses in the ICU environment. Five measures were identified: the six-dimension scale of nursing performance (SDNS), the job performance scale (JPS), the Slater nursing competencies rating scale (SRS), the King's nurse performance scale (KNPS), and the performance obstacles scale. The performance obstacles scale was created specifically for the ICU environment (Gurses & Carayon, 2007), and the SDNS includes a subscale specific to critical care nurses' tasks (Schwirian, 1978), while the remaining three measures are generic. Of the five measurements, only one is a theory-based instrument (Greenslade & Jimmieson, 2007).

The Six Dimension Scale of Nursing Performance (SDNS). The SDNS is a 52-item instrument developed by Schwirian (1978) as part of a research project on predicting successful nursing performance. The 52 items represent 52 nurse behaviors grouped into six performance subscales: leadership (five items), critical care (seven items), teaching/collaboration (11 items), planning/evaluation (seven items), interpersonal relations/communications (12 items), and professional development (10 items). The scale can be used by nurses to obtain performance self-appraisals or by employers for appraisals of performance or perceived adequacy of nursing

school preparation for performance (Schwirian, 1978). The scale uses two 4-point Likert scales to rate the items. The first 4-point Likert scale rates the frequency of a given behavior by the nurse (1 = not expected in this job, 2 = never or seldom, 3 = occasionally, and 4 = frequently). The second 4-point Likert scale rates the quality of the performed behavior. Items 1 to 42 are scored twice using the two rating scales—frequency and quality—and items 43 to 52 are scored solely in terms of frequency. Construct validity was established using a principal component analysis (PCA) from two samples: 914 new nurse graduates and 587 supervisors. The analysis revealed that the subscales were highly congruent between the two groups, and six behavioral subscales emerged. Additionally, the performance subscales differentiated between high performers and low performers. The reliability of the SDNS was reported, with Cronbach's alpha values ranging from 0.84 to 0.98.

The Job Performance Scale (JPS). The JPS is a 41-item scale developed by Greenslade and Jimmieson (2007) for measuring nurse performance in different clinical settings. The scale was informed by the job performance theory of Borman and Motowidlo (1997), which considers task performance and contextual performance as two distinct dimensions of job behaviors that can independently contribute to effectiveness outcomes for organizations (Borman & Motowidlo, 1997; Griffin, Neal, & Neale, 2000). *Task performance* is defined as behaviors directly contributing to the organization's technical core (role requirements), and *contextual performance* is defined as behaviors maintaining the broader social environment, such as organizational support, job-task support, and interpersonal support, in which the technical core must function (Borman & Motowidlo, 1997). Thirty-six items examine task performance behaviors and require nurses to rate on a 7-point Likert scale (1 = much below average to 7 = much above average) how well nurses in their unit or ward complete a variety of activities.

Eighteen items examine contextual performance behaviors and require nurses to rate on a 7-point Likert scale (1 = not at all to 7 = a great deal) how often nurses in their ward complete the activities listed. An exploratory factor analysis (EFA) identified eight behavior dimensions: four task performance dimensions (technical care, provision of information, provision of support, and coordination of care) and four contextual performance dimensions (interpersonal support, job-task support, compliance with organizational rules, and volunteering for additional duties). Greenslade and Jimmieson (2007) have claimed that making a distinction between task and contextual performance in the JPS can provide a solid theoretical base for measuring nursing performance. Internal consistency was established using Cronbach's alpha, with values ranging from 0.91 to 0.94. Convergent validity was established by correlating the JPS with other conceptually similar measures, and criterion-related validity was established by correlating the JPS with an outcome measure.

The Slater Nursing Competencies Rating Scale (SRS). The SRS consists of 84 observable items arranged into six subsections: psychosocial individual (18 items), psychosocial group (13 items), physical (13 items), general (16 items), communication (seven items), and professional implications (17 items) (Nkosi & Uys, 2005; Wandelt & Ager, 1976). This scale focuses on observing nurse performance. Although this scale was originally developed for academic use in the UK to measure student performance, it has since been adapted and used in studies to assess the performance of newly hired nurses in clinical settings in the US (Christman, 1971; Troskie, 1993). Reliability testing was conducted using inter-rater reliability, stability, and internal consistency tests. Inter-rater reliability correlation coefficients were calculated using the scores provided by pairs of observers who had rated the performance of three student groups (n = 74) simultaneously but independently. Values of 0.72, 0.75, and 0.78 were achieved, indicating

modest reliability. Furthermore, the split-half reliability and Cronbach's alpha were 0.98 and 0.74, respectively. However, the Cronbach's alphas for the six subscales were not reported by Wandelt and Ager. However, construct, content, predictive, and discriminant validities were examined and established by Wandelt and Ager (1976).

The King's Nurse Performance Scale (KNPS). Another UK-based instrument for measuring nurse performance is the KNPS, and its development was informed by the SRS (Fitzpatrick, While, & Roberts, 1997). The KNPS scale consists of 53 items and seven domains: physical (14 items focusing on the client's physical needs), psychosocial (six items focusing on the client's psychosocial needs), professional (nine items regarding actions directed toward fulfilling the professional role), the promotion of health and teaching skills (four items focusing on meeting the knowledge needs of clients, self, and others), care management skills and workload organization (six items), communication skills (five items), and use of the nursing process in planning care (21 items). The scale was tested on nursing students who had completed their nursing program (n = 99). Similar to the SRS, the KNPS can also be used in the professional development of newly registered nurses to identify strengths and weaknesses in clinical performance (Fitzpatrick, While, & Roberts, 1997). The Cronbach's alpha for the scale was 0.93, and for the seven domains, the Cronbach's alpha values ranged from 0.46 to 0.72. These low alphas may indicate moderate stability across items secondary to the small number of items in the domains. In addition to the factor analysis, convergent validity was tested against a global care plan score, which yielded a significant correlation (Fitzpatrick, While, & Roberts, 1997).

Both the SRS and the KNPS are generic observational tools that demand 1) that those administering the tests in clinical practice possess significant observational skills and complete

an extensive training program before these measures can be competently used in clinical practice, and 2) that observers adopt an individual or general frame of reference to operationalize a standard of measurement. Consequently, using the SRS and KNPS may lead to an increased risk of observer error.

Performance Obstacles Scale. Gurses and Carayon (2007) developed a 26-item scale to measure performance obstacles in the ICU environment based on qualitative data obtained from a previous study (Gurses & Carayon, 2009). The measure uses two rating scales; 21 items have a dichotomous scale, and five have a semantic differential response format scale (i.e., bipolar scales defined with contrasting adjectives at each end). Factor analysis with Promax rotation and face validity testing was performed, creating 12 dimensions of the performance obstacles construct. These dimensions are patient intrahospital transportation (one item), being a preceptor (one item), dealing with family (four items), physical environment (three items), workspace design (two items), hand-off (four items), inadequate information from physicians (one item), supply area organization (two items), patient chart (two items), medication delivery delay (one item), equipment issues (three items), and patient room supplies stocks (two items). Gurses, Carayon, and Wall (2009) stated that some single items were used alone to represent individual dimensions, yet reliability was not established neither for these items nor for the whole scale due to the use of two different rating scales. Only two subscales Cronbach's alphas were reported: dealing with family ($\alpha = 0.73$) and physical environment ($\alpha = 0.72$). Since this is the only instrument that can assess ICU nurses' performance obstacles, future work is crucial for evaluating the instrument's overall reliability.

The five measures of nurse performance cover similar domains. Examples include communication, collaboration and support, teaching patients, professional development, and

planning and organizing work. This grouping suggests that these domains may be important for inclusion in future measures of nursing performance to ensure a comprehensive examination of nursing behaviors impacting patient outcomes. However, all these measures were designed to assess nursing performance and quality of nursing care in general, rather than to assess care for a specific condition. Therefore, to evaluate nursing care and performance associated with CRRT management, it is necessary to develop a theory-based, situation-specific, and empirically tested instrument.

Furthermore, there is no consensus on the definition and measurement of work performance (Koopmans, Bernaards, Hildebrandt, De Vet, & Beek, 2012; Robb, Valerie, & Dietert, 2002). This inconsistency may be due to the term *performance* being used interchangeably with other concepts including *competence*, *productivity*, *outcomes*, *effectiveness*, *efficiency*, and *quality*. However, performance and quality are not identical or interchangeable concepts because a widely accepted definition of *quality* proposed by the Institute of Medicine (2001) conceptualizes quality as the degree to which health services for individuals and populations are consistent with current professional knowledge and increase the likelihood of desired health outcomes. From this perspective, quality is then considered a proxy of healthcare performance, which is a much broader concept. While (1994) has presented an important distinction between the concepts of competence and performance. Namely, she stated that competence is concerned with perceived skills and therefore cannot be directly measured, whereas performance is an actual situated behavior that can be measured to reflect what nurses actually do in clinical practice. As there is no agreed-upon definition, performance measurement has been conceptualized in multiple ways (Adair et al., 2006; Koopmans et al., 2012). Hence, nursing's contribution to care remains undervalued and understudied due to the poor

conceptualization of nursing performance, inadequate measures of nursing contributions, insufficient information systems to capture and manipulate nursing performance data, and the absence of a standardized language (Dubois, D'Amour, Pomey, Girard, & Brault, 2013; Koopmans et al., 2012). Moreover, there is no common theory-driven schema guiding the nursing discipline, regulatory agencies, and provider organizations in their efforts to define, organize, and operationalize the dimensions of nursing care performance (Dubois et al., 2013; Harris, Vanderboom, & Hughes, 2009) and, by extension, CRRT practice. The field of CRRT care lacks a comprehensive framework by which to guide the implementation of performance assessment activities specific to CRRT practice. For all these reasons, the opinions and experiences of ICU nurses regarding the perceived impact of the ICU environment on their performance and how they practice CRRT are highly important. Thus, for this study, the I developed a theoretically based framework grounded in the context of the ICU environment and CRRT and conceptualized nursing care performance dimensions of CRRT in the ICU. Consequently, I was able to operationalize these attributes and dimensions. Finally, the literature on CRRT mainly focuses on task performance; nothing has been published on contextual performance, and therefore, a qualitative study provided the basis for a description of the contextual performance of CRRT and addressed a gap in the literature.

Work Environment Measurements

Work environment has been extensively studied in the literature investigating nursing shortages and patient safety (Choi, Bakken, Larson, Du, & Stone, 2004; Lake, 2002, 2007). The Institute of Medicine (2004) has documented the need to improve work environments for nurses to promote safe patient care. That is, nurses must practice in a positive work environment to provide safe and quality care. A positive work environment empowers nurses by offering

autonomy, accountability, and control over the work environment (Hoffart & Woods, 1996). Therefore, the organizational characteristics of the workplace can facilitate or constrain professional nursing practice (Kelly, Kutney-Lee, Lake, & Aiken, 2013; Lake, 2002). The term *work environment* is used in the present study to refer to the professional practice environment, described as the system supporting nurse control over the delivery of nursing care, the environment in which care is delivered, and the organizational characteristics that facilitate or constrain professional nursing practice (Aiken & Patrician, 2000; Lake, 2002).

Several instruments have been developed to assess the work environment and applied in many clinical settings, including the ICU. This section provides a description of each instrument.

The Nursing Work Index (NWI). The Nursing Work Index (NWI) was developed in 1989 to investigate nurses' job satisfaction and ability to provide quality care in Magnet hospitals (Choi et al., 2004; Kramer & Hafner, 1989). The NWI was constructed from qualitative interviews, the literature related to job satisfaction and work values, and the characteristics of Magnet hospitals reported in the 1984 American Academy of Nursing Magnet Hospital study. The NWI initially consisted of 65 items. For each item, nurses were asked to think about three statements and respond using a 4-point Likert scale (1= strongly agree; 4 = strongly disagree). The three statements were: 1) "This is important to my job satisfaction," 2) "This is important to my being able to give quality patient care," and 3) "The extent to which the factor is present in my current job situation." The content validity of the NWI was originally addressed using three methods: 1) the instrument's development from Magnet hospital characteristics, 2) an extensive review of the literature, and 3) a critique of the instrument by Magnet hospital researchers. Since only content validity was tested on this scale and no other form of validity was established statistically, the NWI has become outdated in the past 20 years, and some items have come to

resemble a list of factors in the nursing work environment affecting nurse satisfaction and quality of care in the 1980s.

The NWI was expanded in 1991 to measure hospital working environments. The revised measure consists of five subscales to assess management style, leadership quality, organizational structure, professional practice, and professional development (Choi et al., 2004; Kramer & Schmalenberg, 1991). Internal consistency was high within the five subscales, with Cronbach's alpha values ranging from 0.84 to 0.95 (Choi et al., 2004; Kramer & Schmalenberg, 1991).

NWI-Revised (NWI-R). Aiken and Patrician (2000) revised the NWI to create the NWI-Revised (NWI-R) and reduced the scale to 57 items—55 items from the original scale and two newly added items. Moreover, new subscales in the NWI-R were conceptually derived to reflect the traits of a healthy work environment, including autonomy, control over the work environment, nurses' relationships with physicians, and organizational support. Psychometric properties for the new instrument were established. The reliabilities of the subscales ranged from 0.84 to 0.91, and two types of validity were tested: content validity and criterion validity. Content validity was evidenced by Magnet hospital characteristics being used as the basis for the development of the NWI-R items. Criterion validity was demonstrated by the ability of the instrument to differentiate between nurses who worked within a professional practice environment and those who did not, as well as by the measure's ability to identify differences in nurse burnout (Aiken, Smith, & Lake, 1994). While use of the NWI and NWI-R is evident in the literature, both instruments—the NWI (65 items) and NWI-R (57 items)—are considered burdensome for respondents to complete (Gu & Zhang, 2014; Lake, 2002).

The Practice Environment Scale of the Nursing Work Index (PES-NWI). Another instrument developed from the NWI is the Practice Environment Scale of the NWI (PES-NWI). Lake (2002) developed the PES-NWI by selecting 48 items from the original 65-item NWI scale. An EFA was used to identify the 31-item instrument, which includes five salient subscales: nurse participation in hospital affairs; nurse foundations for quality of care; staffing and resource adequacy; collegial nurse-physician relationships; and nurse manager ability, leadership, and support of nurses (Lake, 2002; Warshawsky & Havens, 2011). The first two subscales, nurse participation in hospital affairs and nurse foundations for quality of care, reflect the overall hospital nursing practice environment. The remaining three subscales reflect the nursing practice environment in individual units. The Cronbach's alpha values of the PES-NWI ranged from 0.71 to 0.84. Lake (2002) has indicated that the use of this scale helps build and maintain a quality nursing practice environment. In 2010, a new subscale was added to the PES-NWI to measure nurses' perceptions of the extent to which information technology in their practice environment supports patient care delivery (Moorer, Meterko, Alt-White, & Sullivan, 2009). The new subscale consists of five items and is named the Nursing Information Technology Subscale (NITS). A psychometric evaluation of the NITS was conducted at eight veterans affairs hospitals, and findings demonstrated that this brief subscale has acceptable reliability, convergent validity, and discriminant validity (Moorer et al., 2009). The PES-NWI has been used in studies to identify the relationship between the nursing practice environment, nursing outcomes, and patient outcomes. Higher PES-NWI scores are associated with lower nurse burnout and turnover rates (Aiken, Clarke, Sloane, Lake, & Cheney, 2008); higher patient satisfaction (Boev, 2012; Manojlovich, 2010; Manojlovich & DeCicco, 2007; McCusker, Dendukuri, Cardinal, Laplante, & Bambonye, 2004); lower mortality rates (Aiken et al., 2008);

and fewer ventilator-associated pneumonia cases, medication errors, and nosocomial infections (Kelly et al., 2013; Laschinger & Leiter, 2006; Manojlovich & DeCicco, 2007). Because the PES-NWI has well-established psychometric properties, it was selected by the National Quality Forum as a nursing care performance measure (Lake, 2007; Lake & Friese, 2006). The Joint Commission on Accreditation of Healthcare Organizations has developed specifications for the implementation of the National Quality Forum measures, including the PES-NWI (Johnson et al., 2007).

The Perceived Nursing Work Environment (PNWE). Another modification to the NWI resulted in the Perceived Nursing Work Environment (PNWE) instrument, developed by Choi et al. in 2004. The PNWE instrument has 42 items and uses the same scoring method as the NWI. Seven dimensions are included in the PNWE: professional practice, staffing and resource adequacy, nursing management, nursing process, nurse/physician collaboration, nursing competence, and positive scheduling climate. The internal consistency reliability of the instrument was assessed using the Cronbach's alphas for the entire scale and for each subscale. The Cronbach's alpha coefficients of the first six dimensions ranged from 0.70 to 0.91, while the final dimension, positive scheduling climate, had a low Cronbach's alpha coefficient of 0.56, likely due to this dimension including only three items. The total Cronbach's alpha of the PNWE was 0.95. The validity of the PNWE scale was assessed using a PCA. The PCA revealed the loading of items into the seven previously mentioned subscales. The construct validity of the scale was evaluated by comparing the scores of a subsample of nurses in one state employed by Magnet and non-Magnet hospitals. There were significantly higher mean subscale scores for the nurses at the Magnet hospitals than for those working at non-Magnet hospitals (Choi et al., 2004).

The Practice Environment Index (PEI). Estabrooks and colleagues (2002) established the psychometric properties of the NWI-R in the context of a large Canadian sample of registered nurses (n = 13,185). After the researchers performed an EFA using PCA on the NWI-R, a one-factor solution was forced to test whether subscales could be aggregated. The PCA revealed that one factor explained most of the variance in the data, and thus, a unidimensional scale—the Practice Environment Index (PEI)—was developed. The PEI is assumed to provide a parsimonious index (26 items) of the practice environment in a Canadian context. The Cronbach's alpha of the PEI is 0.92.

The Work Environment Scale (WES). The Work Environment Scale (WES) is an instrument adopted from the discipline of psychology and applied in the context of healthcare systems. The WES was developed by Insel and Moos (1974) and first published in 1981 (Jones, Steffy, & Bray, 1991; Lake, 2007; Moos, 1986). The WES assesses the social climate of work settings, including relationships among employees and between employees and supervisors, and the unit's organizational structure and functioning (Moos, 1986). The scale consists of 90 true or false items and 10 subscales. There are three forms of the WES: the Real Form (measuring employees' and managers' perceptions of their current work environment), the Expectations Form (measuring employees' and managers' expectations of the work environment), and the Ideal Form (measuring employees' and managers' conceptions of an ideal environment). The 10 subscales measure three broad facets of the work environment: relationships, personal growth, and systems maintenance and change. The substantive focus of the 10 subscales is as follows: involvement (concern about and commitment to one's job), peer cohesion (friendly and mutually supportive employees), supervisor support (supervisors who are supportive of employees and encourage mutual support), autonomy (employees are encouraged to be self-sufficient and make

their own decisions), task orientation (emphasis on planning, efficiency, and completing a job), work pressure (work pressure and time urgency dominance in the environment), clarity (employees know what to expect in daily routines and explicit communication of policies and procedures), control (management use of rules and pressure to control employees), innovation (degree of variety, change, and new approaches), and physical comfort (pleasant work environment). The WES has been used to study different clinical settings and highlight the effect of work environment differences across settings. Use of the WES to assess work environment differences has been predictive of nurse job outcomes, including morale, emotional health, satisfaction, burnout, intent to leave, and turnover (Hayhurst, Saylor, & Stuenkel, 2005), and patient outcomes, including hospital-acquired pneumonia, hospital-acquired urinary tract infection, mortality, and patient falls (Houser, 2003). The internal consistency of the subscales was determined by calculating the Cronbach alpha coefficients, which ranged between 0.69 and 0.86 (Moos, 1986). Test-retest reliabilities were also reported. The WES has a moderately high test-retest reliability, and longitudinal studies have found that the instrument is relatively stable over one year (Lake, 2007; Moos, 1986). Concerning the validity of the WES, Moos (1994) has stated that content validity was built into his instrument from the beginning since he carefully defined constructs, prepared items to fit the construct definitions, and selected items according to empirical analysis. Construct validity was established based on the ability of the instrument's subscales to distinguish between two groups theoretically anticipated to be different (Constable & Russell, 1986; Moos, 1986).

ICU Nurse-Physician Questionnaire. Shortell and colleagues (1991) developed an instrument based on a model representing the most comprehensive set of tested managerial practice and organizational process variables affecting ICU nurses performance. The ICU Nurse-

Physician Questionnaire consisted of seven dimensions: unit culture, leadership, coordination, communication, conflict management, team cohesion, and unit effectiveness. Unit culture was measured by 48 items selected from the organizational culture inventory (OCI) (Cooke & Rousseau, 1988). Unit culture had three factors: team satisfaction (emphasis on self-expression, achievement, cooperation, and staff development), people security (emphasis on approval, adherence to procedures, and conflict avoidance), and task security (emphasis on perfectionism, competition, opposition, and authoritarian control). Leadership was measured by eight items to assess the extent to which unit leaders emphasized standards of excellence to their staff, communicated clear goals and expectations, responded to changing needs and situations, and understood unit members' perceptions and concerns. Communication was assessed based on openness (four items), accuracy (eight items), timeliness (one item), understanding (eight items), and satisfaction (three items). Coordination was assessed in terms of within-unit (five items) and between-unit (four items) coordination and the relationships between units (four units). Problem solving/conflict management measured the use of four different approaches to problem solving and conflict resolution: open collaborative problem solving (four items), arbitration approaches (three items), avoidance (three items), and forcing (three items). Unit cohesiveness measured the degree to which people identified with the work unit (five items), and unit effectiveness was measured by assessing perceptions of the absolute technical quality of care provided in the unit (five items) and meeting family needs (two items). Shortell and colleagues pilot tested their instrument in five medical-surgical ICUs in four Chicago hospitals using a sample of 134 nurses and 53 physicians. The pilot test highlighted the need for separate questionnaires for physicians and nurses to achieve greater clarity. Items with low reliability were rewritten, and the coordination items were revised to differentiate between within-unit coordination and between-

unit coordination. The revised instrument was administered to a national sample of 42 medical-surgical ICUs with 1,418 ICU nurses and 790 physicians. The Cronbach's alpha values ranged between 0.61 and 0.88. Convergent validity and discriminate validity were assessed with a PCA.

The Healthy Work Environment (HWE) Instrument. The Health Work Environment (HWE) instrument was developed by the AACN to measure six standards necessary for creating a healthy work environment. These standards (subscales) are skilled communication, true collaboration, effective decision-making, appropriate staffing, meaningful recognition, and authentic leadership (Blake, 2016). For each subscale, there are three items specific to the element of a healthy work environment. The HWE features 18 items scored using a 5-point Likert scale (strongly agree = 5, agree = 4, neither agree nor disagree = 3, disagree = 2, and strongly disagree = 1). A panel of experts has evaluated the HWE for face validity (Blake, 2016). Reliability was tested using two samples (N = 250) of critical care nurses, and the Cronbach's alpha scores were 0.80 and higher. No evidence has been reported regarding other validity tests performed by the AACN or other researchers.

The Healthy Workplace Index (HWPI). The Health Workplace Index (HWPI) is another instrument developed to measure essential components of healthy workplace environments. The HWPI is a 37-item scale developed by Berndt and colleagues in 2009 based on Parsons' Healthy Workplace Intervention framework (Berndt, Parsons, Paper, & Browne, 2009). The HWPI is based on staff empowerment, shared leadership, and participatory change management (Berndt et al., 2009). The HWPI has nine domains: effective nurse staffing systems, excellence in patient care systems, excellence in nursing practice, collaborative relationships, teamwork, behavioral norms, professional development, participatory change management, shared leadership, and workable facilities environment. For each of the 37 original items,

participants were asked to rate, using a 7-point Likert scale with responses ranging from 1 (strongly disagree; not present) to 7 (strongly agree; present), the extent to which each characteristic was present in their unit. For all subscales, except workable facilities environment, reliability values ranged from 0.77 to 0.95. The reliability of the workable facilities environment subscale was 0.58. Content validity was evaluated by eight students and faculty members in a graduate nursing administration program, a psychometrician, and a chief nursing executive of a hospital system. A principal component factor analysis was performed to assess the construct validity, resulting in the emergence of four factors: authentic leadership, excellence in nursing practice, professional development, and structure and process aspects. Thirty-two of the 37 original items were retained for the four factors and collectively explained 73% of the total variance. This four-factor solution was found to possess acceptable psychometric properties, as evidenced by reliability coefficients ranging from 0.88 to 0.93. Furthermore, HWPI factor scores were correlated to five subscale scores of the PES-NWI to determine their degree of shared relationships. The relationships between the PES-NWI subscales and HWPI factors were strong and positive, suggesting that researchers may be able to substitute the HWPI for the PES-NWI to measure healthy workplace characteristics (Berndt et al., 2009).

The Job Characteristics Inventory (JCI). The Job Characteristics Inventory (JCI), a 15-item instrument, was developed from a 1980 survey, which included a series of questions about the characteristics of the respondent's current job (e.g., the amount of variety and autonomy, the opportunity to interact with people and develop friendships, the opportunity to complete tasks, the amount of significance the respondent attributed to his or her job, and the amount of performance feedback received). The survey results led to the development of the JCI to better understand differences in employee productivity and job satisfaction concerning the

work environment (Sims, Szilagyi, & Keller, 1976). Before the development of the JCI, Hackman and Oldham (1975) had developed an instrument called the Job Diagnostic Survey (JDS). Sims et al. (1976) incorporated dimensions of the JDS into the JCI but in a simpler format. The JCI has six factors: variety (employees perform a wide range of operations and the degree to which employees use a variety of equipment and procedures in their work), autonomy (employees have a major say in schedules, equipment use, and procedures), task identity (the extent to which employees control an entire piece of work and can clearly identify the results of their efforts), feedback (employees receive feedback about their performance), dealing with others (the degree to which interaction with others is involved), and friendship (ability to talk and establish informal relationships with other employees). Comparisons of the JCI and JDS by Pierce and Dunham (1978) have demonstrated that both scales tend to collapse to a one-dimensional scale measuring job complexity. Therefore, the JCI was shortened by selecting one scale item that loaded strongly on each of the dimensions of job complexity considered important in earlier research.

The Ward Organization Features Scale (WOFS). Adams and colleagues (1995) developed the Ward Organization Features Scale (WOFS) to identify the "socio-technical work environment" of acute care hospitals by interviewing 97 staff nurses in 14 UK hospitals. The 105-item instrument has 13 subscales across five scales: physical environment (ward facilities, staff organization, ward layout, and quality of ward services), professional nursing practice (professional practice and hierarchical practice), ward leadership and professional working relationships (collaboration with medical staff, collaboration with other healthcare professionals, and cohesion among nurses), nurses' influence (ward management, timing of ward and patient events, and financial and human resources), and job satisfaction. The WOFS has five different

response sets across the subscales, indicating a greater burden on respondents when completing the instrument's subscales. The psychometric properties of the WOFS were established using a sample of 834 nurses from 17 hospitals. Reliability was established by Cronbach alpha calculations and test-retest correlation coefficient tests. Cronbach alpha scores ranged between 0.66 and 0.92 (Adam et al., 1995), and test-retest reliability was examined with an interval of two to four weeks after administering the first questionnaire. The Pearson correlation coefficient of the two scores was computed, and each scale achieved a correlation coefficient of 0.7 or higher, indicating high test-retest reliability (Adam et al., 1995). Validity was established by content validity, criterion validity, and construct validity (factor analysis) tests. The criterion validity of the scales was assessed by comparing scale scores obtained from staff working in six wards who had participated in the survey and a blind observational assessment of ward characteristics.

The Professional Practice Environment (PPE) Scale. In the late 1990s, Massachusetts General Hospital (MGH) in Boston created a shared vision for six clinical disciplines, resulting in the development of the interdisciplinary MGH Professional Practice Model. The model provides a comprehensive overview of professional practice. The core elements of the model are professional staff leadership and autonomy in practice; control over one's practice; collaborative governance and staff participation in decision-making; interdisciplinary communication and teamwork; use of a problem-solving approach to handle disagreements and conflict; enhanced internal work motivation; and delivery of culturally sensitive, competent care to patients of all ethnic groups (Erickson et al., 2004). This model guided the development of the PPE scale, which was used for three years (1999–2001) to evaluate the effectiveness of the MGH

professional practice environment and monitor changes in the environment from year to year (Erickson et al., 2004).

The PPE scale's original 35 items measured eight clinical practice environment characteristics based on the MGH Professional Practice Model core elements: leadership and autonomy in clinical practice (five items), staff relationships with physicians (two items), control over practice (six items), communication about patients (three items), teamwork (four items), handling disagreement and conflict (eight items), internal work motivation (four items), and cultural sensitivity (three items). A 4-point Likert scale was used to assess the degree of agreement with each statement regarding organizational characteristics, and a 6-point Likert scale was used to assess the overall satisfaction for each subscale (Adams & O'Neil, 2008). The internal consistency reliability estimates were greater than 0.75 for the overall scale and the seven subscales, except for the internal work motivation subscale; for that subscale, the figure was 0.63 due to the low number of items (4) in that subscale. Four additional work motivation items for greater response variation were added and reviewed for conceptual congruence with the category definition and other scale items. Another issue with one item in the conflict management scale was identified, and it was found that one item contained two ideas rather than just one, thus creating possible confusion for respondents. Therefore, two items were created to eliminate the ambiguity, resulting in 40 final items in the PPE scale.

In 2002, a psychometric evaluation of the 40-item PPE scale was undertaken using a sample of 849 professional staff; the majority were nurses (n = 717). Two of the 40 items were removed due to the item-total correlation level being below 0.30. The Cronbach's alpha coefficient for the 38-item scale was 0.93, and values ranged between 0.78 and 0.88 for the subscales. Construct validity for the 38 items was established using PCA, which indicated an

eight-factor scale matching the hypothesized dimensions (Erickson et al., 2004). This later version of the PPE is called the Revised PEE scale (Erickson et al., 2004).

The Work Quality Index (WQI). Whitley and Putzier (1994) developed the Work Quality Index (WQI), a 38-item scale based on the available literature and measuring nurses' satisfaction with the quality of their work and work environment on a 7-point Likert scale (1 = not satisfied; 7 = satisfied). The WQI contains six subscales (professional work environment, autonomy, work worth, professional relationships, role enactment, and benefits) established from a factor analysis of data collected from 245 nurses working in a medical center. Cronbach's alpha scores ranged between 0.72 and 0.84 for the subscales, and the overall score was 0.94. Construct validity was also demonstrated using factor analysis. A limitation of the WQI as a practice environment measure is that it measures satisfaction with various work environment characteristics rather than the extent to which these characteristics exist in the work setting. In one hospital, Larrabee et al. (2003) used the professional work environment and autonomy subscales to predict nurse intent to leave. The study demonstrated that the professional environment was predictive of intent to leave and that autonomy was not. An intervention study of a self-directed team structure in two home health agencies resulted in a lower rate of hospitalizations for the intervention agency, but no differences in WQI scores between the two agencies were reported. However, due to the small sample size, the study was underpowered, making it difficult to detect the differences.

The Assessment of Work Environment Schedule (AWES). The Assessment of Work Environment Schedule (AWES) is a 33-item instrument developed based on the available literature to measure the effect of the work environment on nurse job satisfaction and morale (Nolan, Grant, Brown, & Nolan, 1998). The AWES was used to reflect the nursing context in the

UK and the instrument items were created in alignment with Magnet hospital characteristics. The psychometric properties were established using a sample of 676 North Wales nurses. A factor analysis of the AWES, using PCA with varimax rotation, yielded six conceptually meaningful and statistically robust factors: recognition and regard, workload, professional development, quality of care, working relationships (with one's coworkers and manager), and autonomy/decision-making. The Cronbach's alpha of the AWES was 0.93, and the Cronbach's alpha values for the subscales ranged between 0.74 and 0.92.

Fourteen instruments have been reviewed in this section, and although all instruments were developed to assess nurses' work environments, there is substantial variation in the dimensions thought to represent a work environment. Some dimensions are common across instruments; these include autonomy, communication, relationships with colleagues, and leadership. Only two instruments (the WES and PES-NWI) include technology as a subscale to measure its influence on nurse performance and job satisfaction (Moorer et al., 2010; Moos & Insel, 1974), and two instruments (the HWPI and WOFS) have a subscale for the physical environment **(**Adams et al., 1995; Berndt et al., 2009).

Measures should ideally be derived from theory, reliable, valid, appropriate to the unit of analysis, and relatively easy to administer (Shortell et al., 1991). While this review of measures of nurses' work environments revealed instruments with acceptable to strong reliability and validity, only four are theoretically grounded: the HWE instrument (AACN, 2016), the HWPI (Berndt et al., 2009), the PPE scale (Erickson, 2000), and the ICU Nurse-Physician Questionnaire (Shortell et al., 1991). Shaping nursing practice environments to promote desired outcomes requires valid and reliable measures to assess practice environments before, during, and after efforts to implement change. Instruments capable of capturing changes in the work

environment and linking changes to clinical outcomes are required. As such, the present study addresses a pressing need for an instrument based on theory, grounded in the ICU environment, and appropriate to the context of CRRT to assess the impact of the ICU work environment on CRRT practice, quality of care, and patient safety.

Conclusion

CRRT use is increasing dramatically as a therapy of choice for managing AKI, and ICU nurses' roles in managing CRRT are significant. CRRT is a complex and demanding therapy, and ICU nurses are required to have the knowledge and skills to provide high-quality and safe therapy. The ICU environment, where CRRT is carried out, has been examined for its impact on ICU nurses' performance, quality of care, and patient safety. However, no prior study has explored ICU nurses' perceptions about the impact of the ICU work environment on CRRT practice and, by extension, their performance when managing CRRT. Due to there being no theory-based instrument grounded in the ICU work environment and specific to CRRT, a study to address this gap was warranted.

CHAPTER THREE

Methodology

This study's aims were to 1) describe the impact of the ICU work environment on CRRT nursing practice, ICU nurses' performance, quality of care, and patient safety; 2) identify ICU nurses' perceptions of factors in the ICU work environment that influence their performance when managing CRRT as well as quality and safety outcomes; 3) generate a substantive grounded theory of the ICU work environment and CRRT nursing practice; and 4) develop and test an instrument to measure the perceived impact of the ICU work environment on CRRT nursing practice, quality, and safety. An exploratory sequential was conducted in two phases to accomplish these goals. First, a qualitative grounded theory study using DA inductively and deductively generated a theoretical description of concepts and attributes related to the impact of the ICU work environment on ICU nurses' performance, the quality of CRRT practice, and patient safety. Semi-structured interviews were conducted with a purposeful sample of ICU nurses from three adult ICUs at an urban academic hospital. Such data led to a deeper understanding of how ICU nurses manage CRRT, the training they receive, their feelings about the knowledge and skill levels needed to support CRRT, and the ICU environmental factors that impact their performance when managing CRRT. Managing CRRT is a process that the ICU nurses engage in within an ICU and that is professional and social in nature. That is, ICU nurses' performance, the quality of CRRT care, and patient safety are products of interactions between the ICU nurses and their social context.

Once the grounded theory was finalized, a measure was developed to quantify the impact of ICU work environment factors on ICU nurses' performance, the quality of CRRT care, and patient safety. The qualitative results from phase one (dimensions, properties, and conditions)

were used to develop measurement items, variables, and subscales. The measure was then pilot tested on a small sample of ICU nurses. After the pilot study, the finalized measure was distributed to a larger sample of ICU nurses to establish its psychometric properties.

This chapter provides an overview of mixed methods research, followed by a detailed description of each phase of the exploratory sequential mixed methods study procedures used in the study, including sampling, data collection, and data analysis. The chapter concludes with a section on ethical considerations for the protection of human subjects.

Mixed Methods Research

Mixed methods research refers to research in which a researcher combines elements of qualitative and quantitative research approaches for gaining a satisfactory breadth and depth of understanding and corroboration (Johnson, Onwuegbuzie, & Turner, 2007) or, in Green's (2007) words, "multiple ways of seeing, hearing, and making sense of the social world." During the past 25 years, mixed methods research has developed across social and health science disciplines and is considered the "third methodological movement" after the development of quantitative and qualitative research (Tashakkori & Teddlie , 2003).

The central premise of mixed-methods studies is that using quantitative and qualitative approaches in combination provides a better understanding of research problems and complex phenomena than either approach alone (Creswell & Clark , 2011; Johnson et al., 2007). Mixed methods research designs are considered to add value by enabling a more comprehensive and richer understanding of the research problem being investigated by using both qualitative and quantitative lenses. In mixed methods research, investigators can overcome weaknesses inherent in a research approach by combining quantitative and qualitative methods. For example, in quantitative research, the weakness of lacking understanding of the context of a phenomenon or

not directly gathering participants' perspectives can be overcome by performing qualitative research. On the other hand, the difficulty of generalizing the findings from qualitative research to a larger group due to the limited number of participants studied can be overcome by using quantitative methods. Thus, in mixed methods research, multiple data collection methods can be used to answer a research question rather than remaining restricted to methods associated with a specific research approach. Therefore, a mixed methods study is uniquely suited to capture the complexity of CRRT nursing practice in the ICU environment by using different methods to collect data and document ICU nurses' perceptions of the problem.

Definitions of Mixed Methods

Several definitions of mixed methods research have evolved in the literature over time, becoming more numerous, expansive, and nuanced. An early definition came from the field of evaluation and was proposed by Green, Caracelli, and Graham, who defined mixed-methods research as follows:

> a design that includes at least one quantitative method (designed to collect numbers) and one qualitative method (designed to collect words), where neither type of method is inherently linked to any particular paradigm. (1989, p. 256)

This early definition reflects an emphasis on methods, eschewing philosophical concerns. Only 10 years later, however, the definition of mixed methods shifted to include a mix of different philosophical paradigms. Hence, although such combinations are not universally agreed upon as philosophically sound, different ontological, epistemological, and methodological assumptions often comingle in mixed-methods studies, providing a basis for diverse designs and interpretations of results.

In addition to incorporating philosophical issues, later definitions reflect the evolving methodological sophistication of these approaches. In the first issue of the *Journal of Mixed Methods Research*, Tashakkori and Creswell (2007) defined mixed methods research as "research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches and methods in a single study or a program of inquiry" (p. 34). Key to this definition is a focus on methods and methodology and the concept of integrating research findings. This integration or merging of results is now considered a critical criterion for evaluating mixed methods studies (Creswell & Clark, 2011). In the present study, and in accordance with Tashakkori and Creswell's definition, I collected and analyzed qualitative data to explore ICU nurses' perceptions of the impact of the ICU work environment on their performance when managing CRRT, the quality of CRRT care practice, and patient safety, and then used these data to develop an instrument to measure this impact.

The Historical Foundations of Mixed Methods Research

The history of mixed methods research can be traced back to the late 1950s. However, the term *mixed methods* was not coined until the late 1980s. Mixing qualitative and quantitative data was an approach first used in the work of cultural anthropologists and, especially, the fieldwork of sociologists (Johnson et al., 2007). In 1959, Campbell and Fiske published an article introducing the idea of triangulation (referred to as "multiple operationalism"), in which multiple sources of *quantitative* information are used to ensure that the variance of the phenomena explained is not due to methodological artifacts. This article is viewed as the formulation of the practice of using multiple research methods. However, "multiple operationalism" in the form of using multiple data sources (e.g., quantitative or qualitative) in one study is essentially a

construct validation technique and not a comprehensive research design. Today, multiple operationalism is referred to as "multimethod research."

In 1978, Denzin defined *triangulation* as "the combination of methodologies in the study of the same phenomenon" (p. 291) and was the first to outline how to triangulate methods. Denzin also distinguished between within-methods triangulation and between-methods triangulation. *Within-methods triangulation* refers to the use of either multiple quantitative or multiple qualitative approaches, while *between-methods triangulation* refers to the use of both quantitative and qualitative approaches.

In the late 1980s and early 1990s, authors from different disciplines (e.g., sociology, psychology, nursing, evaluation, health sciences, and education) and various countries (e.g., the US, the UK, and Canada) worked to develop the concept of mixed methods as a research approach extending beyond simply using quantitative and qualitative methods as distinct, separate strands in a study (Creswell & Plano Clark, 2011; Tashakkori & Teddlie, 2010). This research approach has been given different names such as *integrated, combined, hybrid, methodological triangulation, mixed methodology,* and *mixed research*. However, mixed methods research is most frequently used and is associated with the *Handbook of Mixed Methods in Social and Behavioral Research* and the *Journal of Mixed Methods Research* (JMMR) (Creswell & Plano Clark, 2011).

Reasons for Mixing Methods

During the past 25 years, several typologies for mixed methods research have emerged, along with associated justifications ranging from general to more detailed. Greene et al. (1989) have identified five broad reasons for mixing methods:

- *Triangulation*: seeks convergence, corroboration, and correspondence of results from the different methods.
- *Complementarity*: seeks elaboration, enhancement, illustration, and clarification of the results from one method with the results from the other method.
- *Development*: aims to use the results from one method to help develop or inform the other method, with development broadly construed to include sampling and implementation, as well as measurement decisions.
- *Initiation*: seeks the discovery of paradoxes and contradictions, new perspectives regarding frameworks, and the recasting of questions or results from one method with questions or results from the other method.
- *Expansion*: aims to extend the breadth and range of inquiry by using different methods for different inquiry components.

Although Greene et al.'s typology of reasons to employ mixed methods research is parsimonious, it has been widely used. However, Bryman (2006) has provided a more detailed list of reasons for using mixed methods. After reviewing 232 methodological and research articles, Bryman devised a list of 16 reasons for mixing quantitative and qualitative methods in a study:

- *Triangulation or greater validity*: the traditional view that quantitative and qualitative research can be combined to triangulate findings for mutual corroboration. If the term is used as a synonym for integrating quantitative and qualitative research, it is not coded as triangulation.
- *Offset*: the suggestion that the research methods associated with both quantitative and qualitative research have their own strengths and weaknesses and that combining these

methods thus allows the researcher to offset the weaknesses to draw on the strengths of both.

- *Completeness*: the notion that the researcher can produce a more comprehensive account of the area of inquiry in which he or she is interested if both quantitative and qualitative research approaches are employed.
- *Process*: the idea that quantitative research provides an account of the structures in social life, but qualitative research provides a sense of process.
- *Different research questions*: the argument that quantitative and qualitative research can each answer different research questions.
- *Explanation*: the use of one approach to help explain findings generated by another approach.
- *Unexpected results*: the suggestion that quantitative and qualitative research can be fruitfully combined when one approach generates surprising results that can be explained by the other approach.
- *Instrument development*: studies using qualitative research to develop a questionnaire and scale items. Such approaches strengthen content validity and improve scale construction and wording based on grounded understandings of the phenomena.
- *Sampling*: situations in which one approach is used to facilitate the sampling of respondents or cases.
- *Credibility*: suggestions that employing both approaches enhances the findings' integrity.
- *Context*: cases in which qualitative research provides contextual understanding while quantitative research uncovers generalizable, externally valid findings or broad relationship among variables.

- *Illustration*: the use of qualitative data to illustrate quantitative findings, often referred to as putting "meat on the bones" of "dry" quantitative findings.
- *Utility or improving the usefulness of findings*: a suggestion, which is more likely to be prominent among articles with an applied focus, that combining the two approaches is more useful for practitioners.
- *Confirm and discover*: using qualitative data to generate hypotheses and using quantitative research to test them within a single project.
- *Diversity of views*: includes two slightly different rationales—namely, combining researchers' and participants' perspectives through quantitative and qualitative research, respectively, and uncovering relationships between variables through quantitative research while revealing meanings among research participants through qualitative research.
- *Enhancement or building on quantitative/qualitative findings*: a reference to making more of or augmenting findings from a qualitative research approach by gathering data using a quantitative research approach, or vice versa.

Bryman's list added to Green et al.'s work, and there are similarities across their lists. For example, "instrument development" and "sampling" in Bryman's list correspond to "development" in Greene et al.'s list. And, "enhancement or building upon quantitative/qualitative findings" and "illustration" in Bryman's list correspond to "complementarity" in Greene et al.'s list. Creswell and Plano Clark (2011) have stated that these lists should be viewed as general frameworks of alternative choices researchers can use to justify mixing decisions. Certainly, Bryman (2006) has indicated that many mixed

methods studies use multiple reasons, and new reasons may emerge while a study is in progress. Additionally, researchers may select the reasons consistent with their studies.

According to Bryman's (2006) list, there were three major reasons for mixing methods in the present study:

1) Instrument development: The qualitative strand was used to develop scale items to measure nurses' perceptions of work factors influencing CRRT nursing practice in the ICU environment.

2) Context: Due to the paucity of research on the impact of the ICU work environment on CRRT practice, the qualitative strand provided a contextual understanding of factors in the ICU environment impacting CRRT nursing practice, the quality of care, and patient safety.

3) Confirm and discover: Dimensions of the ICU work environment and relationships among dimensions were identified. The quantitative strand contributed to assessing the validity of results and generalizability of findings produced based on the data sourced from nurses who engage in CRRT practice.

Mixed Methods Research Designs Typology

In addition to typologies justifying mixed methods, 15 design classifications from different disciplines identified in the literature (Creswell & Plano Clark, 2011). This study followed Creswell and Plano Clark's (2011) classification of mixed methods designs because it is parsimonious, functional, easy to follow and describe, and commonly used. Creswell and Plano Clark (2011) have identified six mixed methods types with four basic designs: convergent parallel (involves separate collection and analysis of quantitative and qualitative data and then

the merging of the results), explanatory sequential (begins by collecting and analyzing quantitative data and then collecting and analyzing qualitative data to explain the quantitative results), exploratory sequential (first exploring a problem by collecting and analyzing qualitative data and then developing an instrument or intervention and testing it in a quantitative study), and embedded design (involves collecting and analyzing both quantitative and qualitative data within a traditional quantitative or qualitative design). There are also two advanced designs: a transformative design (collecting and analyzing data guided by a theoretical framework) and a multiphase design (combining both sequential and concurrent approaches over time to evaluate a program). This study used an exploratory sequential design, discussed below, because the overall aim was to develop an instrument to measure the perceived impact of the ICU work environment on ICU nurses' performance, CRRT practice, quality of care, and patient safety.

Exploratory Sequential Mixed Methods Design

This two-phase design is characterized by one phase sequentially occurring after the other. The first phase was a *qualitative study* that explored the phenomenon through the collection and analysis of qualitative data; during the second phase, a *quantitative study* was conducted to develop and test an instrument based on the data from phase one. The instrument was used to collect quantitative data and subsequently analyzed to establish its psychometric properties (Figure 3.1). Thus, the phase one findings helped develop and inform the second phase. This design was used to 1) generalize qualitative findings from a small sample by conducting a quantitative study using a larger sample, 2) develop and test an instrument when none was available, 3) identify important variables related to a topic, and 4) conduct a study when there was no guiding framework or theory available (Creswell & Plano Clark, 2011).

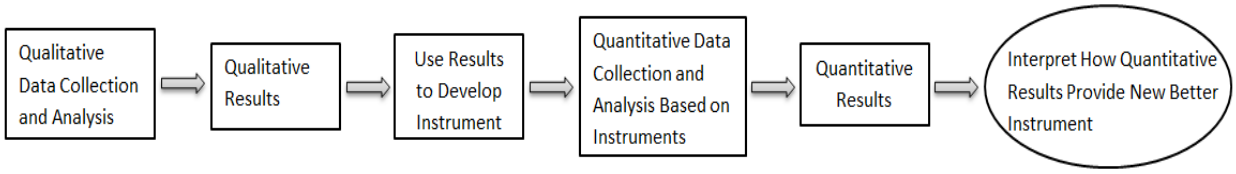

Figure 3.1. The exploratory sequential mixed methods design. Adapted from "A concise introduction to Mixed Methods Research," by J. W. Creswell, 2015. Copyright 2015 by BioMed Central Ltd.

Philosophical Assumptions

Philosophical assumptions in mixed methods research consist of a set of beliefs to guide inquiry (Guba & Lincoln, 2005). Pragmatism is typically associated with mixed methods research (Creswell & Plano Clark 2011; Tashakkori & Teddlie, 2010). However, other philosophies may also underlie mixed methods research. In addition to pragmatism, postpositivism, constructivism, and participatory philosophies may be used.

There are differing views regarding which philosophy best informs mixed methods research. One view recommends adapting the "one best" philosophy as a foundation for a mixed methods study. With this view, researchers have embraced pragmatism as the paradigm of choice in mixed methods research (Creswell & Plano Clark 2011; Tashakkori & Teddlie, 2010). A contrasting view supports the stance of using multiple philosophies in mixed methods research or, as it called, *paradigmatic pluralism* or *multiple paradigms* (Greene & Caracelli, 1997; Greene, 2007; Tashakkori & Teddlie, 2010). Greene and Caracelli (1997) have described paradigmatic pluralism as a dialectical stance in which different paradigms can be used without being reconciled.

According to Greene,

> Important paradigm differences should be respectfully and intentionally used together to engaged meaningfully with difference and, through the tensions created by juxtaposing different paradigms, to achieve dialectical discovery of enhanced, reframed, or new understandings. (2007, p.69)

Thus, when multiple paradigms are used as a mixed methods study progresses, paradigms shift from one phase to another. For this study, constructivism underlay the qualitative strand designed to explore nurses' perspectives on the impact of the ICU work environment on their performance, CRRT practice, quality of care, and patient safety. Constructivism was deemed appropriate for this phase because the participants and I interpreted and constructed a reality based on their experiences and interactions with their environments.

In the quantitative strand, the underlying philosophy shifted to postpositivism to guide the process of establishing the psychometric properties of the developed instrument to measure the perceived impact of the ICU work environment on CRRT nursing practice, quality of care, and patient safety. Postpositivism fits well for this phase as the aim was to maintain objectivity during the data collection and analysis processes and produce a valid and reliable instrument. Moreover, postpositivism is reductionistic, which was consistent with the intention to transform the qualitative findings into a set of items that addressed the research questions and aims.

Phase One: Dimensional Analysis (DA) Grounded Theory

Dimensional analysis (DA) was used to explore the meanings of interactions occurring within the ICU environment when nurses manage CRRT. A variant of the original grounded theory method, DA is a naturalistic qualitative research method for inductively and deductively

generating a grounded theory using an explanatory matrix comprised of dimensions and properties that represent a deeper understanding of a phenomenon in a given social context (Bowers et al., 2009). DA is distinguished from other grounded theory methods by its use of an explanatory matrix as a central procedural and structural form for analysis. Additionally, this method emphasizes delaying conceptual closure and using a natural approach for identifying concepts as opposed to specific tools or methods. DA emphasizes identifying "what all is going on"; in this study, that focus ensured consideration of the environmental contexts and conditions and their influence on ICU nurses, not just social processes. Thus, the explanatory matrix described what ICU nurses do when managing CRRT, what processes occur when managing CRRT, and what influences the quality and safety of CRRT nursing practice in the ICU work environment. As is the case with other grounded theory methods, a constant comparative analysis was used, meaning that all text segments were systematically compared (Charmaz, 2014; Corbin & Strauss, 2015). Therefore, an explanatory matrix was created and continuously revised as data were progressively collected and analyzed. Consequently, DA produced a theory grounded in the data and provided a theoretical and explanatory framework for a complex social phenomenon.

Development of DA

DA was developed by Leonard Schatzman, a student and later a colleague of Anselm Strauss at the University of California, San Francisco. What led Schatzman to develop DA was the scant explanation and demonstration of the analysis process involved in both research and common interpretive acts of grounded theory (Schatzman, 1991; Kools, McCarthy, Durham, & Robrecht, 1996). Schatzman realized that graduate students abated in their research efforts when faced with applying comparative analysis, as described by Glaser and Strauss. His insight was

that complex tools for conducting a comparative analysis, common at the time, are not necessary, owing to the natural analysis almost everyone engages in from childhood. Schatzman believed that rather than remaining engaged with the data, the students were removed from the data. Therefore, his work focused on trying to describe the nature of the analysis one must conduct with qualitative research. Schatzman proposed that when qualitative research is performed, one must follow a natural analytic process (i.e., a "natural analysis"; Robrecht, 1995). Natural analysis was conceptualized as a normative cognitive process generally used to interpret and understand problematic experiences or phenomena (Kools et al., 1996).

After extensive work in teaching field research methods, Schatzman (1991) developed DA and offered it as an alternative procedure for grounded theory. DA was developed with the aim of answering the question "What all is going on here?" (Schatzman, 1991; Robrecht, 1995). The approach is embedded in the epistemological base of symbolic interactionism (Robrecht, 1995; Kools et al., 1996). The main assumption of symbolic interactionism is that "human beings act toward things on the basis of the meanings that things have for them" (Blumer, 1969, p.2). Symbolic interaction suggests that all behavior is based on individuals' interpretations of objects and the meanings they assign to those objects, whether physical, social, or abstract (Blumer, 1969). Assigning meanings to component parts of a situation can help one to note its attributes, context, and process. In addition to symbolic interactionism, constructivism and postpositivism provide the philosophical foundation of DA. The shared epistemological and ontological assumptions among these three philosophies are that perfect objectivity cannot be achieved but is approachable; realities are contextually bound; and realities are constructed from the participants' and the researcher's background, values, meanings, and previous experiences.

Therefore, understanding the meaning of the ICU work environment's impact on CRRT nursing care from the participants' perspectives as well as through analyses of participant actions and interactions can provide insight into the social processes involved.

The Process of DA

DA is a cyclic inductive-deductive analytical process centered around the construction and reconstruction of multiple components of a complex social phenomenon (Kools et al., 1996, p 317). Schatzman (1991) has suggested that analysis requires an understanding that a complex phenomenon is comprised of many parts (attributes). During this analytic process, a person attempts to form a description and logical explanation of a situation by connecting components (dimensions). A *dimension* is an abstract concept with associated properties that provides quantitative or qualitative parameters or modifiers that can help describe a phenomenon (Kools et al, 1996, p 316). These components (dimensions) include context, conditions, processes (actions and interactions), and consequences. These components form an explanatory matrix used as an organizational prototype to move the analysis from describing to explaining a complex situation (Kools et al., 1996). *Context* indicates the boundaries of a situation or environment in which the dimensions are embedded. *Conditions* are the most salient dimensions and dimensions of a phenomenon that facilitate, block, or in some other way shape actions and interactions of individuals in a given situation. *Actions* and *interactions* occurring in specific conditions represent the processes of a phenomenon. Finally, *consequences* are the outcomes of these specific actions and interactions. The following section details the analysis process.

The process of DA consists of two phases (Kools et al., 1996; Robrecht, 1995; Schatzman, 1991):

1- The process of initial coding (data expansion) occurs after the initial data collection. This phase consists of "dimensionalizing," which refers to identifying (designating or naming) multiple concepts (dimensions and their properties) without considering the relationships among these dimensions. Data expansion aims to designate dimensions and their properties to answer the question "What all is involved here?" (Schatzman, 1991). This process can help the investigator identify the parts of the whole and minimize the chance of overlooking salient dimensions that may underlie the explanation of a phenomenon. Data are collected and analyzed until a "critical mass" of dimensions is achieved. When the investigator perceives that major aspects of the phenomenon appears to be reflected in the analysis and determines that a critical mass of dimensions has been reached, he or she can progress to using an explanatory matrix. In the data expansion phase, theoretical memos begin to document the analytical process, and the writing of such memos continues through the final integration of the theory.

2- As subsequent data are collected and analyzed, a sense of the relative importance of each dimension begins to emerge, and a direction for continued analysis is revealed. At this phase, no further data expansion is performed, and the data limitation phase begins by clustering the identified dimensions into more abstract categories and organizing them into a logical configuration that provides meaning. A central dimension providing the most powerful explanation of the phenomenon is referred to as the *perspective* and assumes a key position in the explanatory matrix. This central dimension is constantly evaluated for consistency and verified throughout the analysis process to prevent premature theoretic conception. Moreover, to ensure objectivity, other dimensions are given a conceptual opportunity to be elevated to the status of the perspective. Data

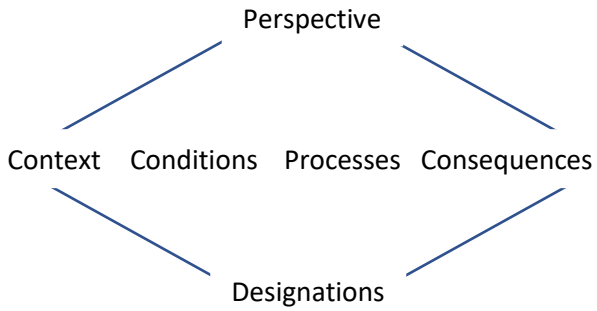

Figure 3.2. The explanatory matrix. Adapted from "Dimensional Analysis: Broadening the Conception of Grounded Theory" by S. Kools, M. McCarthy, R. Durham, and L. Robrecht, 1996. Copyright 1996 by SAGE.

configuration continues until a dimension is found to have the greatest explanation for the relationships among dimensions and ultimately selected as the perspective (Kools et al., 1996; Schatzman, 1991). Once the perspective dimension is selected, the remaining dimensions are relegated as salient, relevant, marginal, or irrelevant. All but the irrelevant dimensions are organized within the explanatory matrix as context, conditions, process, or consequences (Figure 3.2). Dimensions marginal to the perspective are designated as context, and the most salient dimensions are designated as conditions. Theoretical sampling continues to test, clarify, and modify theoretical linkages among dimensions. Integration or novel reintegration of dimensions within the explanation matrix represents the final operation of DA. During this stage, patterns and relationships among the dimensions are described and explained to develop a grounded theory representing the participants' experiences and meanings of interactions within a given condition and context.

Setting

The study was conducted at three ICUs in an urban academic hospital: the cardiovascular ICU (26 beds), medical ICU (16 beds), and trauma and surgical ICU (21 beds). These units were selected because they commonly provide CRRT and have approximately 278 CRRT patient days annually. During the recruitment period for phase one, 98 ICU nurses in these units had completed CRRT training (a four-hour workshop with demonstrations) and been officially deemed competent.

Sample and Sampling

Data were collected from a sample of 14 ICU nurses from the three units. Sample selection was based on the principle of maximum variation sampling defined by Patton (2002), which is "aimed at capturing and describing the central themes that cut across a great deal of variation" (p. 33). In the present study, the goal was to capture a broad spectrum of CRRT nursing management experiences from ICU nurses. ICU nurses may vary in characteristics such as age, years of nursing experience as an ICU nurse, educational preparation, type of ICU, and number of years of experience managing CRRT. In addition to maximum variation sampling, I used snowballing sampling, which refers to participants recommending other possible information-rich cases for the study.

The sample included all ICU nurses who met the following criteria.

Inclusion criteria:

- Registered nurses who worked full-time in the ICU (36 hours per week) to ensure they engaged in CRRT management.

- Minimum experience of one year as an ICU nurse to ensure enough exposure to the ICU environment and completion of unit competencies.
- Completed formal training on CRRT and competency signed off by a preceptor.
- Managed CRRT at least two times in the past six months.

Exclusion criteria:

- Had not experienced all three stages of CRRT management (i.e., initiating, maintaining, and terminating CRRT).

Theoretical sampling, a hallmark of grounded theory, is a data collection method informed by the concepts and themes derived from data. The purpose of theoretical sampling is to collect data that enable the development of rich, robust concepts; uncover variation; and identify relationships and linkages among concepts (Corbin & Strauss, 2015). Theoretical sampling may require re-interviewing some participants or recruiting additional participants to explore new theoretical constructs that emerge during data analysis. Hence, two participants were re-interviewed, and newly enrolled participants were asked specific questions to explore emerging concepts. Theoretical sampling was continuously used to clarify, test, and solidify the conceptual linkages of the theory. Once a consistent level of repetition regarding concepts and their relationships became evident, I found that the collection and analysis of additional data resulted in redundant information and no new concepts were produced. At that point, theoretical saturation was achieved, and sampling ended (Kools et al, 1996).

Recruitment

I approached the division director of Cardiovascular and Critical Care Nursing, ICU nurse managers, and the CRRT practice coordinator to facilitate the study and recruit the sample. I explained the study's purpose and the nature of participation. A letter of site approval for data

collection was obtained from the division director (Appendix 1) and submitted to the institutional review board (IRB). After IRB approval for the study was obtained (Appendix 2), I asked ICU nurse managers to attend a unit meeting to present the study to the ICU nurses. The CRRT practice coordinator maintains an email list with all ICU nurses who are CRRT trained and certified, and shared the email list with me. An initial invitation email was sent to invite ICU nurses to participate in the study. The email included a description of the study, the inclusion and exclusion criteria, and the mode of participation. Additionally, ICU nurses were invited to call a dedicated telephone number or contact me via email if they were interested in learning more about participating in the study. A second email was sent two weeks after the first email to invite ICU nurses to participate in the study.

Procedure

After being contacted by the ICU nurses, I verified each nurse's eligibility and explained the purpose of the study and study procedures following a telephone recruitment and screening script (Appendix 3). Although face-to-face interviews were offered to participants, all interviews occurred over the telephone due to the busy nature of the ICU environment and unwillingness of ICU nurses to extend a 12-hour shift. A disadvantage of telephone interviews is that they occur outside the natural setting of the phenomenon. Nonetheless, that data indicated that participants' descriptions reflected CRRT practice in the selected ICUs. The research consent form was read to participants over the telephone, and a copy was also sent via email (Appendix 4). Then, I obtained verbal consent from the participant. During the informed consent process, I requested permission to contact participants for follow-up interviews. After this consent was obtained, I collected demographic information from participants for descriptive purposes (Appendix 5), as described in the "Data Collection" section below. A convenient date and time for a telephone

interview was determined, and the importance of being in a private location during the interview was emphasized to the nurses to minimize the likelihood of interruption.

Data Collection

Semi-structured qualitative interviews were conducted over the telephone and audio recorded. I obtained verbal consent from the participants at the beginning of the interviews and asked participants to answer demographic questions about their age, gender, educational level, years of experience, shift worked most frequently, type of ICU worked at, and frequency of managing CRRT annually. Telephone interviews were selected as the primary means of data collection due to the busy nature of the ICU environment, nurses' increased workloads, and ICU nurses' unwillingness to stay after shift for an interview due to exhaustion. Previous studies have reported no significant differences between face-to-face and telephone interviewing regarding the quantity or quality of data obtained (McCormick et al., 1993; Musselwhite et al., 2007; Sturges and Hanrahan, 2004; Wilson, Roe, & Wright, 1998). In fact, there are some notable advantages to a telephone interview, as reported by Sturges and Hanrahan (2004), including the following:

- Increased response rate compared to face-to-face interviews or mailed surveys.
- Increased access to participants who are hard to reach due to work schedules, such as in the ICU.
- Increased number of interviews achievable per day.
- Moderate costs.

The interviews lasted approximately 45–60 minutes to ensure the collection of a comprehensive description of the CRRT management process. At the completion of the interviews, $10 gift cards were mailed to participants to thank them for their time. Data were

collected prospectively if a participant was currently managing a patient on CRRT and retrospectively if a participant described experiences managing CRRT in the past six months. I audio recorded interviews using a digital recorder. Interview transcription was conducted professionally using a transcription service. Data were collected using an interview guide (Appendix 6) based on insights from the literature on managing CRRT and performance obstacles related to the ICU work environment, my clinical expertise with CRRT practice, and the SEIPS model. The SEIPS model helped guide questions related to elements of the work system. Participants were asked questions about how they managed CRRT (i.e., process, actions, and interactions), their perceptions of the influence of the ICU environment (context) on CRRT practice (consequences), and issues they had encountered while managing CRRT (conditions) and how they overcame these issues (consequences). The guide included questions such as "Describe what you do after you receive an order to initiate CRRT for your patient?", "What does CRRT quality mean to you?", "What do you do to ensure quality while managing CRRT?", "How do you assess the quality of CRRT?", "What are the challenges you encounter when managing CRRT?", "Tell me about the training and preparation you went through in order to become competent in managing CRRT," "How do you think CRRT training should be done?", "How do you feel about your competency level when you manage CRRT?", and "What factors in the ICU work environment facilitate or hinder CRRT practice?" Demographic questions were also asked at the beginning of the interview. The interview guide was pretested on two ICU nurses (classmates) to assess the clarity and appropriateness of the questions. As data were collected, changes in the interview guide's content were made due to the process of constant comparative analysis as new information appeared after initial interviews. Constant comparative analysis refers to the simultaneous collection and analysis of data whereby both mutually shape

each other (Charmaz, 2014; Corbin, & Strauss, 2008) At this point, theoretical sampling was utilized according to the accepted procedures for grounded theory (Charmaz, 2014; Corbin, & Strauss, 2008). In theoretical sampling, data collection, coding, and analysis occur simultaneously. (More details on data analysis are discussed in the next section, "Data Analysis.") The process of theoretical sampling thus guided the direction of inquiry, the acquisition of later data, and subsequent interview questions. Data collection continued until theoretical saturation was reached, which occurred when data from different participants revealed the same dimensions and no new data emerged in the salient categories.

Data Analysis

First, verbatim transcripts of the interviews were checked for accuracy against the audio tapes. Next, the interview transcripts were read in their entirety to determine the sense of the whole and reflect on its overall meaning. Data analysis was accomplished using computer-assisted qualitative data analysis software (CAQDAS). Dedoose, an online data management software, was used to manage the written de-identified transcripts, field notes, and memos. Dedoose uses encryption and password protection to keep data safe and was used to facilitate data organization, sorting, and analysis.

As previously mentioned, DA involves two phases, a data expansion phase and a data limitation phase (Robrecht, 1995). In the data expansion phase, initial coding occurred simultaneously with data collection, theoretical sampling, and analysis. I started dimensionalizing and designating by labeling and naming a dimension or concept. Each dimension became an abstract symbol with specific meaning within the data and analytic process (Kools et al., 1996; Robrecht, 1995). Several dimensions and their related properties were consequently identified from the data expansion process. Identified dimensions were sorted into

categories based on their analytic meaning. After collecting and analyzing a "critical mass" of data, I began the data limitation phase, which started with category formation. I evaluated each category for its explanatory power and as a potential perspective. Theoretical sampling continued to deeply understand a dimension and helped me to select an organizing perspective. A dimension that captured the complexity of the impact of the ICU work environment on CRRT practice was selected as the organizing perspective. Once the organizing perspective was designated, the remaining categories of context, process (action and interactions), and consequences were placed in the explanatory matrix. Theoretical sampling continued to clarify, test, and refine the theory's conceptual linkages. Once the collection and analysis of additional data revealed no new information, I declared that theoretical saturation had been achieved and discontinued theoretical sampling. I integrated and reintegrated the various pieces of the explanatory matrix to challenge and verify the validity of the emerging theory (Schatzman, 1991). At this point, and once sufficient category saturation and adequate depth of conceptual linkage were reached, the theory generation process was considered complete, and a refined grounded theory statement was reconstituted.

Theoretical memoing was pivotal during the analysis because it made me pause, compare data and codes, and define links between them (Charmaz, 2014). Theoretical memoing is a process for recording my thoughts and ideas as they evolve throughout a study and an intermediate step between collecting data and developing a refined grounded theory. This process was used to provide a record of my analytical thinking and dimensionalizing to ensure the quality and credibility of the data, and as an audit trail to validate the study's trustworthiness and confirmability.

Evaluation of Grounded Theory

Charmaz (2014) has suggested criteria to evaluate grounded theory rigor and divided these criteria into four categories: 1) *credibility*, 2) *originality*, 3) *resonance*, and 4) *usefulness*. Each category consists of a set of questions to help researchers evaluate their research. She emphasized that a strong combination of credibility and originality increases the resonance, usefulness, and subsequent value of a scholarly contribution.

1) Credibility

- Has the researcher made systematic comparisons between observations and between categories?

- Are there strong logical links between the gathered data and argument?

- Are the data sufficient to merit claims?

- Do categories offer a wide range of empirical observations?

- Has the research provided enough evidence for the researcher's claims to allow the reader to form an independent assessment?

2) Originality

- Do the categories offer new insights?

- What is the social and theoretical significance of this work?

- How does the grounded theory challenge, extend, and refine current ideas, concepts, and practices?

3) Resonance

- Do categories portray the fullness of the studied experience?

- Does the grounded theory make sense to the participants?

- Does the grounded theory offer ICU nurses deeper insights into their lives and worlds?

4) Usefulness

- Can the grounded theory spark further research in other substantive areas?

- How does the work contribute to knowledge?

- Does the grounded theory offer interpretations that ICU nurses can use in their everyday lives and worlds?

To assure rigor, I ensured credibility by providing verbatim transcriptions of interviews, demonstrating theoretical saturation when data from different participants revealed no new dimensions or categories, documenting data analysis decisions via theoretical memoing, participating in reflexive journaling, acknowledging my perspective and bias due to strong clinical experience with CRRT management, performing member checking by soliciting participants' views regarding the credibility of the findings and accuracy of conclusions, engaging in peer review and debriefings with dissertation committee members and classmates involved in parts of the analysis, and providing an audit trail and evidence supporting interpretations and yielding thick descriptions (Creswell, 2013).

Originality was established by adding new insights about the impact of the ICU working environment on ICU nurses' performance, quality of care, CRRT practice, and patient safety. I assessed resonance by assuring that the dimensions portrayed the fullness of the experience. Finally, the usefulness of the research is evident because the grounded theory can be used by

ICU nurses to understand the impact of the ICU environment on their performance when managing CRRT.

Phase Two: Instrument Development and Testing

The purpose of the second phase was to 1) integrate the data gained from phase one to develop and refine an instrument to measure the impact of the ICU work environment on CRRT nursing practice, ICU nurses' performance, quality of care, and patient safety and 2) to establish the instrument's psychometric properties. This phase consisted of two phases: a pilot study phase and a national study phase. Thus, a scale was developed and pilot tested on a small group of ICU nurses, and once finalized, the scale was tested using a national sample of ICU nurses.

Scale Development

Development of an instrument with strong psychometric properties requires that the researcher follow a rigorous procedure. DeVellis (2012) has proposed a general approach for item generation and scale development, and a detailed description of each step is provided here.

1- Determine what to measure and ground it in the qualitative data collected.
2- Generate an item pool using short items at an appropriate reading level.
3- Determine the scale of measurement for the items and the instrument's physical construction.
4- Have the item pool reviewed by experts.
5- Consider including validated items from other scales or instruments.
6- Administer the instrument to a sample for validation.
7- Evaluate the items (e.g., item-scale correlation, item variance, and reliability).
8- Optimize scale length based on item performance and reliability checks.

Sample and Sampling

Pilot study. Before finalizing the new instrument, I tested it with a convenience sample of 53 ICU nurses working at an urban academic hospital in two ICUs (Cardiovascular ICU and Medical ICU). Nurses who participated in phase one of this study (interviews) were not included in the pilot.

National study. The sample size for this phase was 310 ICU nurses working in the US, which exceeded the minimum number of 100 subjects required to ensure the stability of the variance-covariance matrix (Terwee et al., 2007).

The population for this phase was ICU nurses with CRRT experience. The sample was recruited from the membership base of the AACN. The estimated total number of AACN members is 500,000 acute and critical care nurses, and the association has more than 240 chapters in 49 states and three foreign countries.

Convenience and criterion sampling strategies were used for both phases. Convenience sampling is a type of nonprobability sampling in which members of the target population who are willing to participate are included. I applied the same inclusion criteria used for the pilot test to assess eligibility to participate in the larger survey. ICU nurses who worked outside of the US were excluded from this study.

Recruitment

Pilot study. ICU nurse managers and the CRRT coordinator were contacted to announce the study and obtain an up-to-date list of CRRT-trained ICU nurses. I aimed to recruit 10–20 participants per unit and visited each unit two times a day, once during the day shift and once during the night shift, carrying closed envelopes containing a study information sheet (Appendix

7), the instrument, and the $10 gift cards. I asked nurses if they wanted to participate in the study and handed them an envelope with study materials if they agreed to participate.

National study. I rented a mailing list from AACN of their members. AACN required the use of a mailing house third party. AACN sent the mailing list to the mailing house company and I sent the company a postcard, including the study website link, to mail it to the AACN members (Appendix 8). Also, I submitted a request to the AACN to post an advertisement in the Call for Action section of AACN's eNewsline (a weekly newsletter emailed to all AACN members) and on the AACN website to ask members to participate in the survey. Posting a call for participation is a free service for AACN members. The call for participation included information about the study's purpose, eligibility criteria, the nature of participation (completion of an online survey), ways of contacting me, and the incentives for completing the survey. Additionally, I posted a call for participation on various Listservs and discussion groups, such as a clinical nurse specialist listserv—hosted by the national association of clinical nurse specialists, advanced nursing practice in acute and critical care—supported by the AACN, and nurses in healthcare management—also supported by the AACN. Since these venues are not exclusively for ICU staff nurses, I highlighted the target population required for this study when posting the call for participants. Finally, I used Twitter to post tweets announcing the study using several hashtags, for example, #ICU, #ICUNurses, #CRRT, and #AACN.

Procedure

Pilot study. Each participant received a package containing the information sheet, the instrument, and a return envelope with my school mailing address. Once a participant completed the instrument, he or she placed the instrument into the enclosed return envelope, sealed it, and

handed it back to me or sent it to me using the internal mail service. Gift cards were handed to participants or emailed to their units after the completed instruments were received.

National Study. A digital copy of the new instrument was developed using the Research Electronic Data Capture (REDCap) survey site. The REDCap site, overseen by OHSU, provides a secure, web-based database application used for building and managing online surveys. A study website was created to host the link to REDCap. The webpage was created using Wix, a free website builder (https://www.wix.com/). The homepage of the study website had information about the study, participation instructions, a copy of the study information sheet, a link to REDCap, and my contact information. Participants were asked to read and print the study information sheet before accessing the survey (Appendix 9). A survey stopper feature was used to ensure the participant's eligibility; if a participant did not meet one of the inclusion criteria or satisfied any of the exclusion criteria, the survey stopped, and the participant was unable to continue. Each participant was assigned an ID number, and this number was used to track survey completion and the date the data were imported into statistical software. Participants could save and return to the survey when it was convenient for them to finish answering the questions.

I applied the following guidelines suggested by Dillman (2000) to improve the survey response rate:

- Respondent-friendly questionnaire
    - Beginning with a welcome screen that is motivational, emphasizes the ease of responding, and instructs respondents regarding how to proceed to the next page
    - Keeping the questionnaire short
    - Beginning with an interesting but simple-to-answer question

    - Using a conventional formula similar to those normally used for paper self-administered questionnaires (e.g., numbered items, left justification, and vertical response choices)
    - Avoiding question structures requiring scrolling or toggling between screens
    - Inserting words and/or symbols that accurately communicate progress toward completion to prevent premature termination
- Multiple contacts
    - Sending a pre-notice (invitation), link to the survey (one to two days after the pre-notice), a first reminder (one week after sending the link), a second reminder (three weeks after the first reminder), and a third reminder (seven weeks after the first reminder), and finally, sending a thank you message
    - Designing an introductory page and first questions that are relevant, fast, and easy
- Personalized correspondence
    - Sending individual email correspondence
    - Using the participant's name
- Token financial incentive
    - Sending the token after survey completion

Data Analysis

Once an instrument had been completed and returned, the data from the pilot study were manually entered into statistical software, and the data from REDCap were exported into statistical software. All data were coded and verified before analysis. The reliability and validity of the scales were examined using SPSS 25 (IBM, 2017).

The following analyses were conducted separately on the pilot study and national study data.

Scale reliability. *Reliability* refers to the extent to which assessments are consistent (DeVellis, 2012). The instrument's scale reliability was assessed based on classical test theory, which specifically assesses internal consistency reliability, a measure of how well the items on a scale measure the same construct and correlate with each other (DeVellis, 2012). Internal consistency reliability was assessed because it is simple to compute, and the instrument scale was only administered once. Cronbach's alpha represents the items' internal consistency. A Cronbach's alpha score is affected by the number of items and the intercorrelation between items. I started by calculating the descriptive statistics to assess for missing data because missing values affect the distribution of scores and Cronbach's alpha. I assessed item variance because when the item variance is small, the shared variance among items is large, leading to a large alpha.

The values for Cronbach's alpha coefficients range from 0 to 1.0. A coefficient of 0 means no reliability, and 1.0 means perfect reliability. Since all tests have some error, reliability coefficients never reach 1.0. Generally, if the reliability of a standardized test is above 0.80, it is said to have very good reliability; if the figure is below 0.50, it is not considered to be a highly reliable test. In this study, and since a newly developed measurement was being assessed, a Cronbach's alpha greater than 0.70 was considered acceptable. I also examined the inter-item correlations for each item to identify items that could be removed to improve the alpha.

Scale validity. *Validity* refers to the accuracy of an assessment and whether a scale measures what it is supposed to measure (DeVellis, 2012). The validity of the instrument was established through a) content validity, b) construct validity via exploratory factor analysis, and c)

concurrent validity. Content validity was tested by asking an expert panel to rate each item in the measurement regarding its relevance to the underlying construct. The panel rated the items using a 4-point ordinal scale (1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, and 4 = highly relevant). Lynn (1986) has advised a minimum of three experts but has indicated that more than 10 are probably unnecessary. Therefore, the expert panel had six members (three ICU nurses, two practice leaders, and one nurse manager). These six members were recruited by sending them invitation emails. Next, I calculated a content validity index for each item (I-CVI). An I-CVI was computed as the number of experts assigning an item a rating of either 3 or 4 divided by the total number of experts (Polit & Beck, 2006). Next, I computed the scale-level CVI (S-CVI). The S-CVI is defined as "the proportion of items on an instrument that achieved a rating of 3 or 4 by the content experts" (Beck & Gable, 2001, p. 209) and calculated by summing all I-CVIs and dividing that sum by the total number of items. An I-CVI and S-CVI of 0.80 or higher is acceptable. I revised, modified, and discarded items based on feedback from the experts.

Construct validity refers to the extent to which a measure adequately assesses the construct it purports to assess (Nunnally & Bernstein, 1994). One way to establish construct validity is to conduct an EFA. Thus, an EFA was conducted to construct a multidimensional scale using the individual items created for this study. The EFA was also used to attempt to reduce the overall number of observed variables into latent factors based on commonalities within the data. Performing an EFA involves four steps: 1) assessment of data suitable for factor analysis, 2) extraction of factors, 3) rotation of factors, and 4) interpretation and labeling (Williams, Brown, & Onsman, 2010). A detailed description of how the EFA was conducted is provided in Chapter 4.

The final type of validity testing was convergent validity, which assesses the correlation between two measures collected at the same time (DeVellis, 2003). To assess this type of validity, I administered the newly developed measurement with another well-developed measure of a related construct, and the correlation between those measures was examined. The construct measured in this study was workload. Workload was measured with the NASA Task Loading Index (NASA-TLX; Hart & Staveland, 1988). The NASA-TLX consists of six scales: mental demand, physical demand, temporal demand, performance, effort, and frustration level. Each scale is divided into 20 equal intervals with verbal anchors of low to high or good to poor (Hart & Staveland, 1988). Each scale score ranges between 0 and 100 (Appendix 10). A weighted score for each scale is calculated by counting the number of times any one scale is rated as more important than the others. Then, an overall workload is computed by multiplying the weighted score by the raw score of each scale. Several researchers have calculated an overall workload score by averaging the raw scale scores without including the weighted score in the calculation. A test-retest reliability of 0.77 has been reported for the NASA-TLX (Hoonakker et al., 2011).

Human Subjects

This study was approved by the IRB at OHSU. I established a rapport with participants and answered any questions they had about the study before beginning the qualitative interviews. Additionally, I discussed with participants that their participation was voluntary, and they had the right to drop out of the study at any time without consequence. Similarly, participants were informed they had the right not to answer questions. There was a potential risk of participants experiencing emotional distress during the qualitative interviews because they could have been asked to share distressing events. However, no incident occurred during data collection. Should such an incident have occurred, the interview would have been paused until the participant felt

comfortable enough to proceed; if he or she decided not to continue in the study, the participant would then have been disenrolled.

To ensure confidentiality, the transcribed interviews, demographic data, signed consent forms, and collected measures had no identifiers that could be linked to participants' identities, and each participant was assigned a unique study identifier (ID number). I kept the code file separate from the data linking the unique study identifiers with participants' names. The data collection files of each phase with the unique study identifiers were password-protected and stored on an encrypted laptop computer. Documents related to the study were filed in a locked cabinet in a locked office.

CHAPTER FOUR

Results

This research study explored ICU nurses' perceptions of factors in the ICU work environment that affect CRRT practice, their performance, quality of care, and patient safety. The specific aims of this study were to 1) describe the impact of the ICU work environment on CRRT nursing practice, ICU nurses' performance, quality of care, and patient safety; 2) identify factors in the ICU work environment that ICU nurses perceive as having an influence on their performance when managing CRRT and affecting quality and safety outcomes; 3) generate a substantive grounded theory of the ICU work environment and CRRT nursing practice; and 4) develop and test an instrument to measure the perceived impact of the ICU work environment on CRRT nursing practice, quality of care, and patient safety. The purpose of this chapter is twofold: first, to describe the dimensions of the grounded theory that explain ICU nurses' perceptions of the impact of the ICU work environment on CRRT nursing practice, performance, quality of care, and patient safety; and second, to describe the process of developing and testing the psychometric properties of The Nurse's ICU-CRRT Environment (NICE) Scale.

Grounded Theory: The ICU-CRRT Practice Theory

The qualitative data collected from the ICU nurses provided important contextual information about the phenomenon of CRRT nursing practice. I captured the stories told by the ICU nurses and described "what all is going on" in the environmental context of the ICU. Managing CRRT is a professional process ICU nurses engage in within ICUs. Furthermore, ICU nurses' performance, quality of CRRT, and patient safety outcomes are products of interactions between ICU nurses and their social contexts.

Sample

Seventeen interviews were conducted with 14 ICU nurses who worked full-time as ICU bedside nurses, had more than one year of work experience in the ICU, and had at least minimally managed CRRT twice in the past six months. In the initial interviews, participants were asked to share their experiences managing CRRT generally and then focus on specific aspects of the phenomenon, such as the CRRT training they had received, their interactions with other team members, their perceptions regarding how the ICU work environment influences their performance when managing CRRT, the quality of the care they provide to their patients, and any patient safety issues they anticipated or had encountered. A few participants were interviewed a second time to gain additional information about emerging themes, clarify information gathered from the previous interviews, and carry out theoretical sampling and member checking. All interviews were conducted over the telephone and audio recorded. The interviews were all transcribed verbatim by a professional transcriptionist service.

Sample demographics. Participants were recruited from three ICUs: the medical, cardiovascular, and trauma units (Table 4.1). The entire sample was comprised of 100% white participants. Fifty-seven percent worked day shifts, and 43% worked night shifts. Including participants who worked day shifts and others who worked night shifts helped me understand variations in CRRT practice. Most participants had baccalaureate degrees in nursing, and two had master's degrees in nursing. Including the two participants with graduate degrees in the sample added greater depth to the description of CRRT practice in the ICU. Fifty percent of the participants had one to five years of CRRT experience while the remaining participants had six or more years of experience. Table 4.1 provides more information about the sample demographics. Sample selection was based on the principle of maximum variation sampling

defined by Patton (2002), which is “aimed at capturing and describing the central themes that cut across a great deal of variation” (p. 33). In this study, the goal was to capture a broad spectrum of CRRT nursing management experiences narrated by ICU nurses. The ICU nurses varied in terms of characteristics such as age, years of nursing experience, educational preparation, type of ICU, and prior experience managing CRRT.

Table 4.1

Study sample demographics

Sample characteristics	Sample (n = 14) n (%)
Unit	
Medical ICU	6 (43%)
Cardiovascular ICU	5 (36%)
Trauma ICU	3 (21%)
Age	
24–34	6 (43%)
35–44	3 (21%)
> 45	5 (36%)
Gender	
Male	4 (29%)
Female	10 (71%)
Race: White	100%
RN years of experience	
1–5 Y	3 (21%)
6–10 Y	4 (29%)
> 10 Y	7 (50%)
ICU years of experience	
3–5 Y	5 (36%)
6–10 Y	2 (14%)
> 10 Y	7 (50%)
CRRT years of experience	
1–5 Y	7 (50%)
> 6Y	7 (50%)
Education	
BSN	12 (86%)
MSN	2 (14%)
Shift mostly worked	
Day shift	8 (57%)
Night shift	6 (43%)

Applying the DA Approach

Using the DA explanatory matrix, I identified factors in the ICU work environment that were perceived by the ICU nurses as impacting CRRT practice, their performance, quality of care, and patient safety. As described in Chapter 3, the dimensions were arranged in the explanatory matrix as perspective, context, conditions, processes (actions and interactions), and consequences. The full model is depicted in Figure 4.1.

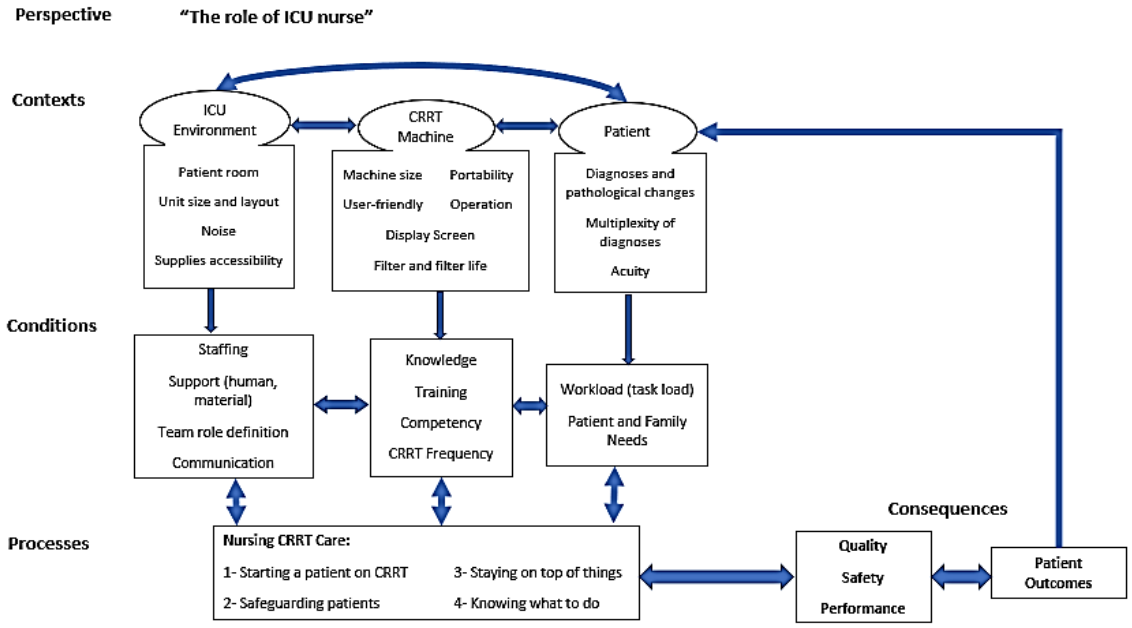

Figure 4.1. The ICU-CRRT practice theory.

Perspective. The perspective, which is a central dimension providing the most powerful explanation of a phenomenon, was found to be "the role of the nurse." Of note, ICU nurses are at the forefront regarding CRRT; an ICU nurse is responsible for setting up the machine, running the therapy, monitoring the patient, troubleshooting issues and raising concerns, and taking down the machine when ordered to terminate therapy. Interestingly, there has been a shift in who

manages CRRT. In the past, CRRT management was shared between dialysis nurses and ICU nurses. Now, ICU nurses are solely responsible for CRRT:

> "Just recently they switched to us initiating CRRT and stopping CRRT—changing the sets and doing that all on our own now."

> "Okay. Well, it's changed a bit. It used to be that you would be responsible for maintaining the running CRRT, but it had been set up already by a dialysis nurse. And now it's changed. Now, we're also responsible for setting it up and maintaining it. We've always been the ones to return back and get them off of the CRRT, so that hasn't changed in the last few years."

This shift in responsibility from dialysis nurses to ICU nurses led to a decrease in the amount of time required to start or restart a patient on CRRT. Previously, when a new order to start a patient on CRRT arrived or if a filter clotted and thus required the therapy to be restarted, ICU nurses had to wait for a dialysis nurse to arrive, which sometimes caused treatment delays:

> "Dependent on when there would be a dialysis nurse available to come set it up. And that would sometimes delay getting somebody started [on CRRT]. And now we're able to do it ourselves."

> "In between when a filter clots off, you can just start them back up on a new circuit right away, as opposed to having to wait for someone to come get it restarted for you. So, it's helped us keep the continuity of our care plan going for the patients. It's better for the patients."

Delays in connecting a patient to CRRT occurred more often during the night shift than during the day shift. During night shifts, dialysis nurses were usually on call, and it could take

them a substantial amount of time to travel to the hospital, prime the CRRT machine, and connect the patient to the CRRT machine. Alternatively, the task of restarting CRRT was sometimes delayed until the day shift:

> "When the dialysis nurses used to do it, especially at night, there were often very big delays because they weren't in the hospital necessarily at night."

> "When I was back on nights, I never once had them call in somebody. It was always, 'Oh, we'll just wait till morning, and we'll get them done on morning.'"

When the ICU nurses became responsible for completely managing CRRT, they came to feel more independent and in control of CRRT:

> "It has changed a lot with CRRT. Right now, we're pretty much independent. We set it up, change filters. I can't think of an instance where we would call a dialysis nurse to come help."

The role of the ICU nurse is not limited to managing the CRRT machine but extends to reporting changes in patient condition, monitoring patient response to treatment, ensuring availability of fluid and medications related to CRRT, coordinating care with other providers, safeguarding the patient, and educating patients and families about CRRT.

The ICU nurses described CRRT as a high-risk, complicated modality that can place the patient at risk of injury, bleeding, and infection, similar to other treatment modalities in the ICU potentially possessing the same possible risks. There are physical task burdens and repetitive processes associated with CRRT. For instance, ICU nurses need to lift a five-liter fluid bag to hang on the CRRT machine, change fluid bags and take them down, chart fluid obtained via CRRT and fluid output hourly, and monitor pressures to ensure the smooth operation of therapy:

> "The entire modality is high risk—high risk of injury to the patient—but, also, it's complicated, but it's not especially complex if you have a fair body of knowledge….We do so many things in the ICU that have huge risks of injury associated with them. I don't think that this particular modality is any more risk than any other, but you do have to make sure that your knowledge is up to date."

Contexts. Contexts are the boundaries of a situation or environment in which dimensions are embedded. I identified three contexts central to CRRT: the ICU work environment, the CRRT machine, and the patient's condition.

Patient. Patients requiring CRRT to support their kidney function tend to be sicker and hemodynamically unstable. Furthermore, most patients have multiple diagnoses and complex care needs. For example, a patient might have, in addition to AKI, cardiac issues, liver failure, or cancer:

> "My first CRRT patient was very sick, and I think they were doing CRRT; they were very sick and the symptoms they had were becoming unmanageable."

> "Those individuals, if they end up in the ICU with us, are often very sick and have many body systems and many organs that are not working very well."

> "They are very, very sick to the point of maybe not surviving, waiting for the organ."

The CRRT machine. The CRRT machine has undergone technical advancement in the past three decades and has thus become easier to set up and operate. The CRRT machine has a large, bright display to increase the accessibility of the information on the screen. The machine is portable and relatively small, making it easy to move and place anywhere in a patient's room:

> "The machines were a little bit different back then. They alarmed if you bumped them. They were not nearly as user-friendly as they are today."

> "It's just a machine, and they have certainly become easier with the changes that have happened over time."

> "The machine is portable and small enough to fit into our rooms."

The CRRT machine gives clear and easy-to-follow step-by-step instructions on setup and troubleshooting problems. While setting up the machine has become easy, that task may take time.

> "The CRRT machine when you start it kind of walks you through each step that you need to do, and so if you've followed the steps, most of the time it does exactly what it's supposed to do."

> "It's very easy to find a solution to whatever issue arises."

> "I would say generally it is the physical setup of the device takes a lot [of time]."

Modern CRRT machines use a filter that mimics the function of a kidney. The filter has 72 hours of continuous functioning, and after these 72 hours, the filter's efficiency decreases. The machine measures the pressures in the filter and tubes to alert the operator if the filter is clotting and must be changed. Intensive care unit nurses monitor these pressures hourly to assess the filter's patency and efficiency:

> "[Filters] have to be changed in 72 hours. Once you start up the machine, it starts counting. After a certain amount of time if it's still running on the same set, it will tell you to change it."

The ICU environment. Attributes of the ICU environment relevant to CRRT are the patient room design, the unit design, noise, and the accessibility of supplies. The design of a patient room can impact how CRRT is performed. For instance, small patient rooms become crowded when multiple devices are in the room in addition to a CRRT machine. This room configuration causes issues with maneuvering or reaching equipment when providing care:

> "You know from a physical sense, our rooms are small. Sometimes that's kind of hard, especially if you have a patient that's ventilated and on CRRT. It's kind of hard to maneuver around."

> "Maneuvering around the room can be difficult with the CRRT machine in place because generally a CRRT machine is one of a multitude of devices that are connected to the patient."

Redesigning ICU patient rooms can impact ICU nurses' work. Intensive cause unit patient room designs that have pylons hanging from the ceiling help nurses to maneuver equipment easily:

> "Things that make it easy, in our unit in particular, the wall hookups, suction, medical oxygen, air, vacuum, all that kind of stuff, is on moveable pylons that attach to the ceiling and can be maneuvered around the room."

Furthermore, when CRRT is being administered, the ICU nurses need to keep extra CRRT supplies on a cart—depending on the size of the patient room—either inside the patient room or outside the patient room near the room door, where supplies for smaller rooms are stored. The size and the layout of the ICU also impact the accessibility of CRRT supplies:

> "All the filters are kept in the supply room, and I think the layout is great.…everything is accessible."

> "Yeah, as far as supplies for it, they're in our medication supply room. But then the actual dialysis bags that we're exchanging are kept on a cart right at the patient's bedroom."

> "When we have a CRRT going, we tend to keep the CRRT supplies near the room, so you don't have to go very far, and we stock general things in the room that you would need. You know if I needed a new set or something like that, I would have to walk to the other side of the unit to get it, but again the unit is not that big, so it wouldn't take very long. Or I could just ask one of my neighbors to go get it for me, and they would be able to do that."

As previously stated, the CRRT machine mimics kidney functions, and the output is collected in a five-liter bag. Once a bag is full, the nurse must replace it with an empty one. The full bag must also be drained. Therefore, nurses either carry the bag to a dirty utility room or empty it into the patient's toilet. Some units have drainage ports in the rooms, and in these cases, the ICU nurses hang the full bags on IV poles and connect the bags to the drainage ports with no need to leave the patient room.

In addition to patient room and unit size, noise in the ICU environment caused by multiple equipment alarms also affects patient care. The CRRT machine, like all equipment in the ICU, uses alarms to alert the operator. Consequently, if patients are not sedated and intubated, it is difficult for them to sleep:

> "With the CRRT alarm I have to change bags, so it's kind of hard for those people to sleep, and so a lot of time they end up kind of getting some ICU delirium because people are in and out of their rooms constantly 24 hours a day while they're on CRRT."

> "We have to leave the doors and the windows open, so we can see all the machines, so it never really does get dark or quiet."

Interactions among the ICU environment, CRRT machine, and patient. The role of the ICU nurse is bound to the ICU work environment, CRRT machine, and patient, and these three contexts interact with and influence each other. For example, a very sick patient with multiple problems might require CRRT in addition to other therapies, resulting in multiple types of equipment in the room, with multiple alarms sounding, and supplies kept nearby to manage care easily.

Another example is that a patient's condition may impact the ability of the CRRT filter to function properly. Usually, an anti-coagulant agent is administered via the CRRT machine to prevent blood from clotting. However, an example was provided of a patient with disseminated intravascular coagulation (DIC) who could not receive an anti-coagulant agent, increasing the chance of the filter clotting and resulting in stops in therapy. This situation was complex and sometimes frustrating:

> "Just that since the patients are so critically ill, it's just that other—normally it's not just one part of their body. It's not just the CRRT part that's not working well in their bodies sometimes. They're septic or they're having cardiac issues or that sort of thing that can affect how the machine works. If you're in liver failure, oftentimes they may go into DIC,

> or something will get [heparin-induced thrombocytopenia] HIT or something like that, and so then that complicates it as well."

> "Other things that I've run into are, you know, of course, just patient-specific things where just recently I had a patient that had a big clot formation in his line and actually stopped the machine abruptly. It happened two times in a row for absolutely no known reason…It occurred abruptly so you couldn't return the blood both times, so that was a little frustrating."

Conditions. Conditions are dimensions facilitating, blocking, or in some other way shaping actions and interactions of individuals in a given situation. I identified the conditions listed below as impacting CRRT care, ICU nurses' performance, quality of care, and patient safety. Conditions are organized in relation to each context.

Conditions related to the ICU environment. Conditions related to the ICU environment that can facilitate or block ICU nurses from providing CRRT care are staffing, support, the role of ICU medical teams and nephrology teams, and communication.

Staffing. Adding CRRT to a patient care plan means that a nurse is assigned to a single patient. The nurse-patient ratio immediately changes from 1:2 to 1:1:

> "Well, once a patient is determined that [he] would need the CRRT, if they were a patient that had been a paired assignment, it does require that your coworkers and your charge nurse—they have to restructure staffing because one nurse has to be dedicated to that patient now."

> "In our ICU they're always one-to-one, so we only have that patient. We don't have any other patients."

If the patient's condition is unstable and he or she is receiving other treatments in addition to CRRT, the nurse-patient ratio changes to 2:1 (i.e., two nurses share the care of one patient). One nurse focuses on CRRT while the other nurse administers medications and takes responsibility for the remainder of care:

> "If they're on CRRT and they have another cardiac device or something else on top of that they'll add another nurse."

> "The way we kind of divide it up is one nurse is doing everything patient-care-wise, and medicines, and turning, and bathing, and all of that stuff, and then the other tends to do just the machine, and then usually the intakes and outputs because that's usually related to how you're calculating your volumes for your CRRT."

Support. Receiving support is crucial for ICU nurses when managing CRRT. This support was identified as both human support and material support. Human support emerged in the data as support from colleagues, nurse managers, charge nurses, nurse educators, ICU nurses from other units, and dialysis nurses. Intensive care unit nurses receive support for CRRT from other ICU nurses on the unit, which makes the process of CRRT care much easier. There is typically someone who can help set up and troubleshoot a CRRT machine, and the charge nurse is usually CRRT trained and can be a great source of help for nurses during the shift:

> "A lot of people who have been doing CRRT the most years, those people are, in general, charge nurses and support nurses."

> "A lot of times it's just a lot easier if we can just use each other."

> "So, at least on our unit, when we do the setup, we have another nurse who's also CRRT trained come in and go through the setup with you. So, there's two of you there to offset

the possibility that your critically ill patient may need attention in the process of that, so it's not one person in there doing it all by themselves."

Support for CRRT is also provided by ICU nurses from other units. For instance, the participants reported reaching out to other ICUs if they need help with troubleshooting. In addition, although ICU nurses are now fully responsible for managing CRRT, dialysis nurses are still available to help with troubleshooting the CRRT machine if the ICU nurses cannot resolve the issue:

"Usually we just call maybe nurses from other units to come and troubleshoot with us if we're having a problem with the machine."

"Sometimes we will also check in with our dialysis nurses if there are some troubleshooting questions that come up that we can't figure out ourselves. We'll use them as a sounding board."

The participants indicated that it is helpful to have someone physically present when troubleshooting a CRRT machine. However, over-the-phone support is also available for ICU nurses when needed. The CRRT machine manufacturer provides the option for ICU nurses to call a 1-800 hotline number at any time to guide them through solving technical issues:

"I mean, I know [company name] has, like, a 1-800 hotline with a nurse to, I guess, stay to hang around and answer time-sensitive questions regarding CRRT."

"Changing the sets and doing that all on our own now—and the support we have for that is over the phone."

Material support was described by the participants as a source of support, including having a policy and procedure (P&P) manual, manufacturing manual, and CRRT binder attached to CRRT machines with step-by-step instructions and guidelines. A P&P manual is also available in the unit at the nursing station. Additionally, an electronic copy of the P&P manual is available via the hospital intranet. Intensive care unit nurses have computers in their work areas and are thus able to navigate the electronic P&P manual and find the required information. The CRRT binder was made by the unit and contains the information presented in CRRT training, such as the PowerPoint presentation slides used in the class:

> "The manufacturer of the machine produces a manual of how—where to find things, how to set things, how to do the procedures—it's like what they teach us in class. There's the manual for the machine that's out there."

> "Policies and procedures are always accessible through the intranet and are fairly easy to search and find and pull up."

> "Binder for CRRT and it has all the steps in there: what do you do to start the set, how do you stop the set, like, common troubleshooting issues and numbers to call. They have a big binder there if you need to remember, to refresh your memory about how to do it."

Role of intensivists and the nephrology team. Once a patient exhibits signs of impaired kidney function, intensivists refer the patient to the nephrology team. The nephrology team assesses the patient's condition and decides if CRRT is appropriate given the patient's condition. Nephrology subsequently orders CRRT and reviews the patient's condition and progression daily. The ICU nurses report the results of blood work and any changes in the patient's condition and confirm CRRT restart after filter clotting with the nephrology team. These nurses clearly

understand the role of each team member, which makes communication easier. But, if the patient's condition deteriorates, the intensivists can order the CRRT to be halted and review the care plan after the patient's condition stabilizes:

> "Yeah, so there's the primary team. And those doctors can usually see where this patient is heading, that they're eventually going to need some kind of dialysis intervention. It also involves the nephrology team coming to consult and confirm the best plan for this patient."

> "So, [the nephrology team] write[s] the orders for CRRT, and they write sets of parameters to notify them if a patient goes outside those parameters with their pH or their electrolytes or something."

> "Changes in the patient condition would be addressed directly with the trauma team who has full preview over calling [CRRT] off and discontinuing. Nephrology is just a consult while trauma retains certain directives of authority."

Communication. Communication around CRRT between the intensivists and nephrology team was described as effective because there are clear role definitions for each team regarding who is responsible for what. However, there were times when participants felt that communication between the two teams was confusing:

> "I feel like most of the time, the communication between the nephrology team and the ICU team is adequate, not excellent, but most of the time, it's adequate. So, there are some days where I will have a patient on CRRT where the ICU team has a different goal than the nephrology team does."

> "Sometimes, it is confusing from the bedside shift or from the bedside nurse perspective, finding out or determining which goals we're going to use, the nephrology team goal or the ICU team goal."

Furthermore, participants reported that communication with the nephrology team varies between the day shift and night shift. During the day shift, the nephrology team visits the patient, reviews the patient's condition, reviews the CRRT orders, and revises the orders if needed. In contrast, the availability of the nephrology team during the night shift is limited. During night shifts, CRRT orders are seldom changed, and reaching an on-call nephrology fellow is sometimes challenging:

> "I have never had a nephrology physician come to bedside at night."

> "It would be really cool if there was more communication with nephrology on night shifts."

> "They're [nephrologists] only reachable by page—by electronic paging. I have had some difficulty with getting nephrology to return calls overnight but have always been able to escalate things to attendings that call me back very quickly."

Conditions related to the CRRT machine. Conditions relating to the CRRT machine center around CRRT training, competency, and frequency of use on a unit. These three conditions were found to impact each other.

Training and knowledge. The ICU nurses received CRRT training and had their competency verified before they could independently manage CRRT. The training took the form of classes with a hands-on demonstration. After attending a training session, the participants then shadowed a colleague for one shift:

> "I had two or three days class work, and those were full eight-hour days where we had not only a rep from [company name], which is the circuit we use but also the CRRT coordinator, who was also doing a lot of the education. There were two days of class, then one full 12-hour shift with a preceptor. Then we are on our own."

> "My first CRRT assignment was done with a preceptor after receiving formal training from the [company name] RN educator that came through town at the time. And, I was assigned a patient on CRRT with another nurse who had at least a year or so of experience running CRRT, and I ran the majority of it while they answered questions and ensured competency."

The ICU nurses stated that the hands-on training they received had successfully prepared them to operate and troubleshoot a CRRT machine. Specifically, they appreciated the hands-on experience using the same machine they had on their units as part of the training they received. The ICU nurses indicated that the CRRT machine is just like any other machine they use in the ICU; the more hands-on experience managing CRRT they had, the more confident they felt:

> "The [company name] representative who explained the function and operation of CRRT was of great benefit and provided direct, sort of realistic knowledge about hands-on operation."

> "It's just experience like with anything else. The more we do it, the more we learn about what happens. We took some classes and we did the training and everything, and I think that's fine. With CRRT in general, you can take a bunch of classes, but you just have to do it. You just have to run the machine and do it for a while before you figure out how to manage things and what kind of things to expect."

Although the CRRT training the ICU nurses received developed their confidence in managing CRRT, they felt nervous the first time they handled a CRRT machine due to the high level of risk associated with the treatment:

> "Yeah, I don't remember particularly feeling like I wasn't ready. Like I said, just feeling nervous because it is a high-risk intervention, but it's—I didn't feel like I wasn't ready. I felt like I had gotten the training and the orientation."

> "I remember being nervous because it's a modality that is invasive and you have a lot of control over what's going on with the patient. So, I remember feeling nervous."

Competency and CRRT frequency. The more participants were provided with the chance to practice their skills in managing CRRT, the more competent they became. However, based on the type of ICU, the frequency of having patients on CRRT varies. For example, in the medical ICU, nurses encounter CRRT more frequently than nurses in the cardiovascular ICU. This reality means that newly trained ICU nurses sometimes have to visit another ICU to shadow a nurse managing CRRT to complete the training requirement of shadowing a CRRT-trained ICU nurse for one shift:

> "The frequency is different than other modalities, so I think, at that time, maybe I'd see one maybe once a month or something."

> "We do it fairly often on our unit, so we're all pretty used to it."

> "The first time that I oriented the CRRT, I actually floated to a different unit and was oriented on a trauma patient…so it was when I was in the cardiac medical ICU. And I floated down to trauma and had a CRRT patient."

Infrequent management of CRRT had created an issue for some participants because ICU nurses are required to have a certain number of CRRT patient assignments annually to maintain their competency. In the ICUs where the participants in this study work, ICU nurses are required to have a minimum of five patient care days annually to maintain their CRRT competency. A patient care day can be achieved by caring for a patient on CRRT during the entire shift or having contact with a patient, which can occur by relieving an ICU nurse for a break and changing a fluid bag while watching the patient. Five contacts are equal to one patient care day:

> "If you are helping somebody, that counts as, like, a contact, and five contacts are the equivalent of a patient care day."

> "If you are relieving somebody for a break, then that is a contact that they still get kind of credit for helping, as you're listening for alarms and changing bags and things while people are on break. So, those contacts actually count towards maintaining competency."

The purpose of setting the patient care days requirements for CRRT is to ensure that all CRRT-trained ICU nurses have the opportunity to stay competent regardless of the frequency of CRRT on their units. Infrequent CRRT administration on a unit results in the unit limiting the number of ICU nurses authorized to receive CRRT training. While this approach helps CRRT-trained ICU nurses meet competency requirements, on some occasions, no other CRRT-trained ICU nurses are available during a shift to help or offer relief for breaks. In such cases, the charge nurse asks other ICUs for help:

> "We don't necessarily have a large number of CRRTs, and so not everybody was getting their patient care dates. And so, what they decided was this is a way that they could

ensure that people who are still having hands-on experience with the device were getting credit for that."

"And then in the instance where things are really crazy, and we don't have enough CRRT coverage, we'll reach out to other units like we did that night or that day with trauma. And they came down and gave us a break."

Conditions related to the patient. Conditions related to the patient are workload and patient and family needs.

Workload. As previously described, once CRRT is ordered, the nurse-patient ratio changes to 1:1 because of the increased workload. The workload increases due to the repetitive tasks nurses perform hourly when managing CRRT in addition to the fact that patients who receive CRRT are critically ill:

"I have to be in there every hour. I have to write down CRRT numbers every hour. I have to check fluids every hour."

"I mean they understand that they can be complicated patients and that they need to be by themselves with just one nurse managing just that one patient."

"[CRRT] is a time-intensive process that potentially limits task prioritization for other things."

Furthermore, the shift in responsibilities in setting up a CRRT machine from nephrology nurses to ICU nurses increases ICU nurses' workloads:

> "And then just recently we've been doing the putting up the sets ourselves. That's been a new skill we've had to learn. And initially it was a little harder just to try and figure out how to do all of that, just a little more added to your workload."

> "Sometimes I have somebody on CRRT who is, like, bleeding at the same time and having to get constant blood transfusions that I have to kind of monitor. That part of it along with the CRRT, obviously that takes my attention away from the CRRT, but not all the time, and that's just kind of how ICU patients are even if they're on CRRT."

Patient and family needs. CRRT creates unique patient and family needs that ICU nurses have to address when managing CRRT. First, the participants reported that families, and sometimes patients if not sedated, do not fully understand CRRT, despite having signed a consent form authorizing treatment. The participants observed a knowledge deficiency regarding CRRT. Consequently, ICU nurses spend time explaining to family members what CRRT is, its use, and what to expect:

> "It seems like they offer that to families and families don't understand what CRRT is. They don't understand what that means and when you have all of the components of operating that and how that might actually make the patient more uncomfortable plus an outcome that's not expected to be good."

> "I think you know if you're not a medical person, you can only understand it so much. They tell you your family member is fine and the only way they're going to survive is CRRT, then most people are going to say yes. Most people don't understand what it means to be on CRRT."

Receiving CRRT means that the patient's movement is restricted to ensure access line patency. The CRRT machine is connected to a vascular access line (i.e., a line inserted into a large vein, such as the internal jugular vein in the neck or the femoral vein in the groin). The patient has to lie straight to ensure the access line remains unblocked. This restriction of patient movement means that ICU nurses need help when turning a patient to change the patient's position and relieve pressure areas to prevent the development of decubitus ulcers:

> "Although, it is very infrequent that a CRRT patient moves from bed to bed or goes anywhere. They generally sit real still."

> "You have this huge IV line in your neck that's really uncomfortable, and you can't really get up and walk around. You can't really move that much because you have this big line in you."

Processes. According to DA, *processes* refer to the actions and interactions occurring in specific conditions of a given phenomenon. The focus of this study was on CRRT nursing care and all factors that affect the care provided by ICU nurses. Four processes emerged from the data: starting a patient on CRRT, knowing what to do, staying on top of things, and safeguarding patients. While the presentation of these processes may seem linear, they are intertwined. All these processes center on planning, monitoring, managing, reporting, and coordinating CRRT care. This section intentionally describes the conditions previously identified—staffing, support, workload, and communication—to demonstrate the perceived impact of these conditions on the four processes.

Starting a patient on CRRT. The process of starting a patient on CRRT is the situation or interaction occurring when ICU nurses are assigned a patient in need of CRRT. The process of

starting a patient on CRRT may seem straightforward but was described as complex. The decision to start a patient on CRRT is controlled to a great degree by the medical team. Specifically, the participants in this study reported that physicians do not listen to them regarding the suitability of CRRT for a patient, initiation of CRRT early in the course of treatment, or shifting from hemodialysis (HD) to CRRT as an option to manage blood pressure:

> "I feel like there are a number of patients that we have that are—their blood pressures are definitely soft and that it seems like they would tolerate CRRT better than they tolerate HD. And they tend to pretty much always go for HD first, which I understand."

> "Sometimes [nephrologists] don't take into consideration how the nurses feel about that patient and whether they feel like they would be more stable on CRRT versus the bigger hemodynamic changes that happen with HD."

> "I feel like a lot of times, we do advocate for CRRT, and it doesn't happen until we've gotten to the point where either that patient is about ready to code and then does code by the time that we actually get things going because, again, and a lot of that did have to do with the delay in getting the machine up and the people up to actually put somebody on dialysis."

The ICU nurses also noted that discussions about starting a patient on CRRT happen late, potentially delaying the therapy. Additionally, the delay in deciding to initiate CRRT complicates the process, which starts with inserting a vascular access line. Participants believed that insertion of an access line before the patient's condition deteriorates, which makes insertion difficult due to hemodynamic instability, should be afforded stronger consideration by the medical team:

> "If we actually started that process of talking about CRRT earlier, we could intervene before they have time to have such a profound acidosis that it actually contributes to coding."

> "If we could decide that earlier, then I feel like we wouldn't have those patients become as unstable because we would be able to get them on CRRT before they had such a profound acidosis that they code and die."

The process of starting a patient on CRRT can also be delayed during the night shift due to the lack of availability of on-call nephrology residents, as discussed in the "Conditions related to the ICU environment" section (under "Communication"). The decision to start a patient on CRRT tends to be pushed to the day shift when more staff are available:

> "I have several vivid memories while I was on night shift of a patient who really needed to be put on dialysis, and we waited and waited, and then, once they finally decided, it was too late because by the time—you know, you have to decide to put somebody on CRRT, but then realize that once you make that decision, you still have several hours."

Then, once the discussion about CRRT starts and the decision is made to start a patient on CRRT, a delay in doing so can stem from the availability of ancillary services such as laboratory and X-ray services. For example, after the ICU nurses assist intensivists with inserting a vascular access line, the new access line placement needs to be confirmed by X-ray before it can be used. Delays in completing this step sometimes occur when X-ray technicians are unavailable. Another cause of treatment delay is long wait times for laboratory test results:

> "We place a line to do CRRT, but the X-ray tech is busy, and we need to verify the placement before we can start them. We send a lot of labs for CRRT, and that can affect

your workload, and it can be difficult if we are waiting on labs to make these pretty important changes in their care."

"When you start a CRRT, you have to do labs every two hours. So, if it takes an hour and a half to get your labs back, you don't have time to correct anything before you send your next set. Sometimes that can be frustrating."

Thus, the interviews revealed that the process of starting a patient on CRRT is sometimes delayed due to decisions made by the medical team and a lack of available support services, especially during the night shift. Discussing the initiation of CRRT before the patient's condition worsens and improving the availability of support services may reduce or eliminate these delays.

Safeguarding patients. Participants stated that the process of safeguarding patients involves the use of strategies to ensure the safe practice of CRRT. Safeguarding patients appeared in the data as double-checking CRRT orders, CRRT training access requirements, and maintaining competency levels. These strategies include both institutional policies and ICU nurses' actions to safeguard patients.

The double-checking of CRRT orders means that before connecting a patient to a CRRT machine, two ICU nurses verify the CRRT orders and match the orders with the CRRT machine settings. Because CRRT is considered a high-risk procedure, it is critical for ICU nurses to ensure that settings are correct. Not only are the CRRT orders checked against the CRRT machine settings, but two ICU nurses also double-check the fluid bags and all medications before administration. This double-checking process also happens at shift change during hand-off. The sending nurse and the receiving nurse review all CRRT orders and machine settings:

> "Another nurse checks the bag with you to make sure it's the same as what is recorded in the computer and the rate is correct."

> "At the nurse hand-off we'll double-check the bags that are ready."

In addition to double-checking CRRT orders, the process of safeguarding patients includes limiting CRRT management and training to senior ICU nurses. New nurses do not start CRRT training and are not assigned to a patient on CRRT during their first two years. The safeguarding process here aims to ensure that a new nurse has sufficient time to gain competence as an ICU nurse first before adding more advanced skills:

> "To be a CRRT nurse, you have to have a little bit of tenure in ICU and on the unit that you are working on. A patient that is on CRRT is not getting taken care of by a new grad or anything like that."

Furthermore, organizational competency requirements to ensure ICU nurses are competent and remain competent when managing CRRT are considered important for patient safety. As previously mentioned, the CRRT-trained ICU nurses in this sample are required to achieve a minimum of five patient care days annually to maintain competency. The organization tracks this requirement to ensure compliance:

> "The management always makes sure that only people who know what they're doing get CRRT patients."

In conclusion, safeguarding patients is a process ICU nurses follow to protect their patients from potential harm because of the high risks associated with CRRT. And, safeguarding is a multistep process initiated, enforced, and monitored by organizations.

Knowing what to do. Knowing what to do refers to situations or interactions between ICU nurses, their patients, and the CRRT machine. Intensive care unit nurses must possess the knowledge and skills necessary to manage CRRT safely and achieve therapy goals. Intensive care unit nurses have to know how to set up the CRRT machine and follow the CRRT machine's step-by-step instructions. As discussed earlier, the ICU nurses receive training that prepares them to independently manage CRRT and are given support by other CRRT-trained ICU nurses on their unit or other ICUs. Additionally, once CRRT is started and continues to run, the ICU nurses need to know how to read and interpret the information received from the CRRT machine and intervene accordingly. The information the ICU nurses have to know is the amount of fluid removed from the patient hourly, the pressures in the filter and circuit, filter patency and signs of filter clotting or clogging, and the steps to follow to return blood to the patient when ending the treatment or before filter change. Essentially, this knowledge is a mental checklist of knowing what to do:

> "We just looked at all of our pressures, looking at how old the set was, if we were having issues with any pressure lines, if the lines were reversed—kind of going through a checklist of things, so to speak, not a physical checklist but just a mental checklist of all the things we needed to be paying attention to with the CRRT. And then hourly getting our volumes and writing down our pressures and documenting those."

> "If you're running [CRRT] and your filter keeps getting clogged and you're having to change that a lot because maybe they're really septic or something. Their condition is changing and learning to read what's happening with the CRRT kind of lets you know what's happening with your patient and then anticipating if you know what's going to happen."

Fluid removal was reported as one of the main goals of connecting a patient to a CRRT machine. Intensive care unit nurses receive an order to remove a certain amount of fluid from the patient as a therapy goal. Every hour, ICU nurses monitor and calculate how much fluid the patient received and how much fluid was removed. Based on this information, ICU nurses must determine how much fluid to program the machine to remove in the next hour. Hence, ICU nurses must know how to accurately and correctly calculate fluid removal because otherwise, they could miss a therapy goal by removing too much or too little fluid:

> "I think initially—it's another whole other thing you have to pay attention to and it can be a little intimidating at first, but then once you learn how to do it and realize it's just math—and as long as the machine is running well, all you're doing is doing math and making sure that you're correctly documenting your I's and O's, looking ahead to say, 'Okay, I've got three IV piggybacks, so the computation should be this much more volume. I'm gonna have to remove this much more volume.'"

A fluid removal order is one of the orders ICU nurses receive when their patients are on CRRT. A set of orders or a protocol is written by the nephrology team instructing the ICU nurses on what settings to input into the CRRT machine, what treatment parameters to follow when replacing electrolytes, and the laboratory parameters requiring notification of the nephrology team:

> "It's an order set, so everything kind of comes—they just order it and it's one big group of orders all together—they set what mode it's in and they set what kind of filter we should use and how fast it's running initially, like what to start it at, and how much fluid to pull off or not if that's not our goal. And then any other drips that may be associated with that, like calcium if they're getting citrate and that sort of thing."

> "When I get my labs every four hours and I say, oh, my potassium is 3.2. Let me go to my protocol. It says if potassium is below 3.4, replace with 40 milligrams of potassium chloride. And it's something I can get out of the—on the shelf by myself. I don't have to have anybody cosign anything because it's totally independent within my scope and the order set."

In conclusion, knowing what to do was reported as constituting a critical and continuous process to ensure patient safety. As mentioned in the "Conditions related to the CRRT machine" section, only CRRT-trained ICU nurses can relieve each other for breaks. If there are no other CRRT-trained ICU nurses available during the shift in the ICU, the in-charge nurse is responsible for offering relief for breaks if he or she is CRRT trained or for asking someone from another ICU to help.

Staying on top of things. The final process related to CRRT practice that emerged was staying on top of things. This process centers on coordinating care and prioritizing work. A large portion of this process is dedicated to ensuring that adequate CRRT supplies are available throughout the shift. CRRT supplies, such as fluid bags and medication administered with CRRT, are mainly sourced from a pharmacy. The participants need to ensure that there is enough number of fluid bags availability in the unit because if they run out of CRRT fluid bags, therapy cannot continue. Therefore, clear communication and coordination between ICU nurses and the pharmacy are considered crucial by the participants:

> "Usually the pharmacist is in charge of making sure you have enough of the fluid bags to run the CRRT."

A pharmacist usually visits during the day shift and assesses the patient's fluid and medications needs. Based on the CRRT protocol, a pharmacist estimates the amount of dialysis fluid needed in a 24-hour period and has the bags delivered to the patient's room. However, during night shifts, the availability of a pharmacist to physically visit the bedside and assess patients is limited, and thus, it becomes the nurse's responsibility to coordinate with the pharmacy and request more fluid bags to be delivered to the unit:

> "Usually, the pharmacist will come and check with you at the beginning of the shift and see that you have enough to go for the entire shift. Then, also, with EPIC, we just have a little sticky note that we say, 'Hey, I'm down to the last bag of this type of fluid'. And they're very responsive in getting me whatever I need."

> "So you kind of have to notify the pharmacy because at night there's no actual pharmacist in the ICU at night. They're only there during the day."

The rate of dialysis fluids can change during the shift, which might happen due to changes in a patient's condition requiring an adjustment of the CRRT orders. In this case, an ICU nurse must estimate the number of fluid bags required for the remainder of the shift and inform the pharmacy about this change in supplies:

> "If they're busy or if it's nighttime and they change the flow rates, then maybe you might need to remind them to send you more bags. You kind of have to stay on top of that."

> **"**Sometimes the fluid bags run out faster than you expect, and so you have to make sure to plan for that and make sure the pharmacy is sending things up to you in a timely manner."

In addition to maintaining enough supplies throughout the shift, the ICU nurses stated that they must stay on top of things when prioritizing care. As mentioned in the "Conditions related to the ICU environment" section (under "Staffing"), due to the increased workload caused by adding CRRT to a care plan, the nurse-patient ratio changes to 1:1, and if the patient's condition is complicated, requiring more attention, another nurse is also assigned to the same patient, and the nurse-patient ratio then becomes 2:1:

> "When there's multiple devices it's always busy, but you just try to stay on top of it… recently when I've had a patient on CRRT and [extracorporeal membrane oxygenation] ECMO, it's a two-to-one assignment, so another nurse was in the room as well."

In conclusion, CRRT can increase an ICU nurse's workload. This increase in workload forces ICU nurses to develop the need to stay on top of things; they must always plan, anticipate events, and coordinate supplies in a timely manner to ensure that CRRT continues to run without interruption.

Consequences. *Consequences* are outcomes resulting from actions, strategies, or processes ICU nurses experience when managing CRRT in the ICU work environment. Consequences of the impact of the ICU work environment on CRRT practice, as perceived by ICU nurses, are quality of care, patient safety, and performance consequences.

Quality consequences. Critically ill patients with AKI have a serious need for dialysis support, and due to their hemodynamic instability, CRRT is sometimes the best option. When CRRT is provided to these patients at the right time, they are better able to tolerate the therapy. Conversely, a delay in starting CRRT can lead to a worsening of the patient's condition to the point that he or she may arrest before being connected to the CRRT machine. Starting

discussions about providing a patient with CRRT and involving ICU nurses in the decision-making process can positively impact the condition of critically ill patients:

> "I think that all of these patients I am taking care of definitely need CRRT, and I have been pretty amazed at the people I have taken care of have been able to recover."

And when the decision is made to start a patient on CRRT, it is imperative that therapy be started quickly. Actions such as inserting an access line and having the placement confirmed by X-ray without a delay, having the ICU nurses prime and ready the CRRT machine for connection, and receiving the necessary supplies for CRRT in a timely fashion, whether during a day shift or a night shift, can improve the ICU's ability to provide CRRT to the right patient at the right time.

Safety consequences. Patient safety was reported by the participants as being maintained when the processes of safeguarding patients are implemented firmly and continuously. Double-checking and verifying CRRT orders and CRRT machine settings before connecting a patient to the CRRT machine and at shift hand-offs help prevent mistakes and maintain patient safety. Furthermore, the policy of ensuring that only those who are CRRT trained and competent can be assigned to patients on CRRT enhances safety. Furthermore, ensuring coverage by CRRT-trained ICU nurses for breaks is a form of continuously keeping an eye on the patient:

> "The fact that you have a CRRT nurse cover breaks for a CRRT patient, with eyes on the filters and stuff, is a really good practice for patient safety."

Moreover, supporting ICU nurses, when needed, by providing extra staff to help with non-CRRT care helps ICU nurses focus their attention on CRRT:

> "Sometimes they're so sick that you have the CRRT line, but they have a lot of other issues as well that you're trying to manage at the same time. It can be hard to focus on the CRRT component if there are a lot of other things going on."

Focusing on the CRRT and patients' needs, continuously monitoring the CRRT machine, and having other staff available are believed to enhance patient safety. Failure to implement these safeguards compromises the ICU's ability to achieve desired patient outcomes.

Performance consequences. The ICU nurses claimed that their performance when managing CRRT could be measured by their ability to achieve therapy goals, their knowledge of what to do when the CRRT machine alarm sounds, and their ability to start and keep a CRRT machine continuously running. However, uncontrollable factors that could negatively impact their performance were reported. For instance, a patient's condition can interfere with a nurse's ability to achieve CRRT goals. The ICU nurses are responsible for achieving therapy goals such as removing a certain amount of fluid from a patient. This task was reported as challenging when the patient's condition is both critical and changing fast:

> "I think each day, we're set with—we have a fluid goal and an [intake and output] I&O goal for our patients. I suppose that evaluating whether you achieved that goal would be sort of an indicator, but that isn't something that solely rests on the nurse's shoulders if you don't achieve that goal. The patient's condition sort of determines that."

Another example provided of an uncontrollable factor was a lack of available resources and supplies, which negatively impacts ICU nurses' performance. For example, if there is a delay in delivering CRRT fluid bags to the unit, ICU nurses cannot perform their jobs appropriately or provide the required treatment for their patients:

> "Well, it does seem that there is always something that we're missing. There's that day when I find, 'Oh, we're out of this supply. We're out of this medication.' And that's just in general—not just CRRT. CRRT—there's a stronger focus because if you run out of something, then you generally can't do the treatment. So, they're very good at making sure you have whatever you need. But it does seem that we run out of something on a regular basis, though what the something is changes from day to day."

It is important to note that conditions and processes can have multiple consequences simultaneously. For example, participants reported that when staffing is limited, and there is no second CRRT-trained ICU nurse available to relieve them for their breaks, this situation can seriously jeopardize their ability to perform effectively due to fatigue, which can lead to errors and decrease the quality of CRRT care:

> "I mean it increases fatigue levels. Doing CRRT for 12 hours straight can be—it is a very repetitive process. Not getting breaks and not getting lunches, the research is already out there. It leads to higher risk levels. More fatigue, potential for error."

In summary, this section has identified four CRRT nursing care processes and eight conditions in three interacting contexts—the ICU environment, the CRRT machine, and patient. These conditions and processes affect the role of the ICU nurse (i.e., the organizing perspective dimension) when managing a patient on CRRT. Starting a patient on CRRT, safeguarding patients, knowing what to do, and staying on top of things are processes that the ICU nurses stated they apply when managing CRRT. These processes only take place when the ICU work environment has adequate staffing, available supports, distinct role definitions of team member responsibilities, clear and open communication, effective training, maintenance of competencies, and manageable workloads. Successful implementation of these four processes enhances quality

of care, safety, and performance. The following section describes how I used the qualitative findings to inform the development of a measure to assess factors in the ICU work environment and the perceived impact of these factors on CRRT nursing practice.

The Nurse's ICU-CRRT Environment (NICE) Scale

After the development of the ICU work environment and CRRT nursing practice grounded theory, I initiated the process of developing the Nurse's ICU-CRRT Environment (NICE) scale. The purpose of developing the instrument was to enable the assessment of the factors ICU nurses perceive as affecting their CRRT practice and to quantitatively present these factors. The process of developing the instrument consisted of the following steps:

- transforming qualitative codes and quotes into questionnaire items
- providing a panel of experts with the instrument to assess its content validity
- revising items and creating a revised instrument based on feedback from the expert panel
- pilot testing the new instrument with a group of ICU nurses locally
- analyzing the pilot study test results with a focus on assessing the reliability of the new instrument
- revising the instrument based on the pilot study results and administering it to a national sample of nurses
- assessing the instrument's reliability and validity
- confirming the final structure of the new instrument

Transforming Qualitative Codes and Quotes into Items

The process of creating items started by taking each dimension and examining the related codes and quotes in that dimension. For example, under the dimension *CRRT machine* and the

accompanying code *setting up the CRRT machine*, I transformed the quote "the CRRT machine when you start it kind of walks you through each step that you need to do, and so if you've followed the steps, most of the time it does exactly what it's supposed to do" into "CRRT machine gives clear instructions for setup." I tried to preserve the meaning of the qualitative data and transform the data into short, easy-to-read items. Initially, 70 items were developed with at least 10 items under each dimension. A second look at the 70 items was taken, and eight items were deleted due to duplication, which resulted in 62 items. These 62 items were then sent to the dissertation committee members for feedback. After meeting with the committee and discussed their feedback, items were reworded for clarity, and two items were deleted to avoid redundancy. Ultimately, the instrument was reduced to 60 items.

Assessing Content Validity

Content validity is defined as the degree to which an instrument has an appropriate sample of items for the construct being measured (Polit &Beck, 2004, p 423). I formed a panel of experts to assess content validity. Six CRRT experts (three bedside ICU nurses, one CRRT coordinator, and two ICU CNS/educators who teach and train nurses on CRRT) were asked to rate the items. The raters were asked to rate each item based on relevancy and clarity on a 4-point scale. For relevancy, each item was rated as 1 = not relevant, 2 = needs some revision, 3 = relevant but needs minor revision, or 4 = very relevant. For clarity, each item was rated as 1 = not clear, 2 = needs some revision, 3 = clear but needs minor revision, or 4 = very clear. Only the relevancy ratings were used to calculate content validity. In addition, raters were asked to comment on each item, suggest a revised wording of an item, or suggest a new item if they wished.

Calculating the Content Validity Index (CVI)

Two CVIs were calculated for this instrument. The first type calculates the content validity of the individual items and is called the content validity index, item level (I-CVI). The second type of CVI calculates the content validity of the overall scale (S-CVI). The I-CVI was calculated for each item by dividing the number of raters assigning a rating of 3 (quite relevant) or 4 (highly relevant) to an item by the total number of raters. For instance, if an item was rated 3 or 4 by five of six raters, then the I-CVI for that item is 5/6, which equals 0.833. For a panel of six or more raters, Lynn (1986) has recommended an I-CVI minimum threshold of 0.78 to deem an item acceptable. In this study, the I-CVI scores for the instrument's 60 items ranged between 0.17 and 1.0. Ten items scored an I-CVI of less than 0.78.

The second type of CVI calculated for this instrument was the S-CVI. The S-CVI was computed as an average score, or the S-CVI average (S-CVI/Ave). There are several ways to calculate the S-CVI/Ave. The approach I followed was to sum all I-CVIs and divide the total by the number of items. This approach focuses on the average item quality rather than on the average performance by the rater. The S-CVI/Ave for the instrument's 60 items was 0.88. After I deleted the items with an I-CVI value lower than 0.78, the S-CVI/Ave increased to 0.92. The literature suggests that an S-CVI/Ave of 0.80 or higher is acceptable (Polit & Beck, 2006). However, Waltz et al. (2005) have advised using 0.90 as the standard for an acceptable S-CVI/Ave.

Revising Items and Creating an Instrument

As previously mentioned, 10 items had I-CVI scores of less than 0.78. Five items were deleted, but the other five items were maintained and reworded as needed. I kept these five items because the related codes appeared frequently in the qualitative data; it is possible that the items'

wording caused raters to disagree. The following section provides a detailed explanation of each item revision.

Item numbers 12, 19, 29, 32, and 40 were deleted (see Appendix A). Item number 12 was considered more general and was not CRRT-specific. Since there was another item that discussed the accessibility of supplies and because the I-CVI for item number 12 was 0.50, it was deleted. Item number 19 was deleted because it had the lowest I-CVI score (0.16), and there was general agreement among the raters that this item was not relevant. Item number 29 was deleted because it was related to the preference of the ICU nurses to set up the CRRT machine by themselves and not to have this action performed by dialysis nurses. The raters thought such a preference was not a factor that could impact CRRT practice. Item number 32 had an I-CVI score of 0.67 and was deleted because it overlapped with item number 33. Item number 40 had an I-CVI score of 0.50 and was deleted because the raters though it was vague. Additionally, there were two other items that measures training (items 37 and 39), so item 40 was removed to avoid redundancy.

The five items kept were item numbers 2, 33, 36, 47, and 48. Item number 2 had an I-CVI of 0.67 and was retained because the related code appeared frequently in the data. Of the six raters, three reviewers assigned a rating of 4 for item number 2 and one gave it a 3. The item refers to the ability of nurses to move the CRRT machine and change its location within the patient room. This item was reworded to make it clearer; “The CRRT machine is easy to move around” was revised as, “I can move the CRRT machine easily in the patient room.” Item number 33 had an I-CVI of 0.67 but was kept after rewording because it overlapped with item number 32. Therefore, I deleted item number 32, as mentioned earlier, and maintained item number 33, which previously read “Despite having been through the informed consent process,

families and patients often request further information about the CRRT process." This item was changed to "Despite having been through the informed consent process, families and patients often request further information about the CRRT process from me." Item number 36 had no comments from the raters but had a low I-CVI score (0.67). I kept the item without rewording because it appeared frequently in the data. Item number 47 had an I-CVI of 0.67, and two raters thought the item's wording was confusing and unclear. Therefore, item number 47 was kept with rewording. This item read, "CRRT is ordered properly based on the patient's prognosis most of the time" and was changed to "CRRT is ordered for patients with poor prognosis some of the time." Item number 48 had an I-CVI of 0.67 and was kept because the raters thought it was relevant but required greater clarification. Thus, item 48 was changed from "Most of the time CRRT is started too late" to "Most of the time CRRT is started too late in the patient's course of treatment."

One item was deleted despite having a good I-CVI score. Item number 42 ("CRRT is not frequently used") had an I-CVI of 0.83 but was deleted because there was another item discussing competency issues due to low frequency of experience with CRRT (item number 38). Since I wished to shorten the instrument but maintain a representative sample of items relevant to the construct measured, items 42 and 38 were combined to become "Every year I have a hard time maintaining my CRRT competency due to low frequency of CRRT patient assignments."

After removing six items and rewording those in need of revision, as discussed above, the total number of items was 54. Table 4.2 lists the names of the new instrument's subscales and the number of items in each subscale.

Table 4.2

The new instrument's subscales and the number of items in each subscale

Subscales (dimensions)	Items
CRRT machine operationality and functionality	9
Structure and physical layout	5
Patient condition and family education	4
Support	7
Role definition and communication	3
Workload	4
Training, competency, and knowledge	5
Performance	3
Quality	5
Safety	9
Total	54

Pilot Testing the New Instrument

After the new instrument with 54 items was finalized, 24 demographic questions were created to describe the sample when analyzing the data. A hard-copy survey was then distributed to the participants. Data collection for the pilot study occurred from June 14, 2018 to July 17, 2018. I recruited from two ICUs, the medical ICU and cardiac ICU at OHSU. The total number of subjects enrolled was 65, and 53 participants completed the survey, resulting in a robust response rate of 81%. Before data entry, each survey was assessed for item completion; 48 surveys were 100% complete, and five surveys were 98% complete. Therefore, all 53 surveys were included in the analysis. The surveys were coded and manually entered into SPSS 25. Another study member verified the coding and data entry of the data set. After completing data

verification, the data set was checked for outliers and data missingness. A missing value analysis revealed no outliers. Table 4.3 lists the score means, standard deviations, and prevalence of missing values for each item. The rates of missing values were generally low (< 4%). In addition, the missing data pattern was found to be completely random, as a Little's MCAR test of the data was not significant (Chi-square = 256.672, DF = 262, Sig. = 0.581).

Table 4.3
Mean scores and percent missing for the individual items

			Sample size (n) = 53
	Mean	SD	% Missing
MA1	4.45	.695	.0
MA2	3.64	1.094	.0
MA3	4.62	.562	.0
MA4	4.04	.831	.0
MA5	4.33	.760	1.9
MA6	4.47	.608	.0
MA7R	2.92	1.071	.0
MA8R	2.92	.681	1.9
MA9R	3.81	.833	.0
SP1R	2.60	1.080	.0
SP2R	4.00	.679	.0
SP3R	3.17	.871	.0
SP4	3.68	.827	.0
SP5	3.23	.993	.0
PCF1	4.45	.722	.0
PCF2	4.21	.661	.0
PCF3	2.58	.887	.0
PCF4	3.23	1.012	.0
SU1	4.81	.395	.0
SU2	3.89	1.050	.0
SU3	4.02	.720	.0
SU4	3.87	1.001	.0
SU5	4.15	.718	.0
SU6	3.94	.842	.0
SU7	3.89	.640	.0

Table 4.3.
Mean scores and percent missing for the individual items (continued)

			Sample size (n) = 53
	Mean	SD	% Missing
RDC1	4.26	.486	.0
RDC2	3.94	.842	.0
RDC3	4.13	.735	.0
WK1	4.25	.782	.0
WK2	3.34	1.091	.0
WK3	3.10	1.107	1.9
WK4R	3.00	1.066	1.9
TCK1	4.06	.602	.0
TCK2R	3.66	.999	.0
TCK3	4.36	.558	.0
TCK4	4.45	.607	.0
TCK5	3.04	1.073	.0
P1	4.15	.601	.0
P2	4.45	.574	.0
P3	3.05	.834	.0
QUL1	3.81	.841	1.9
QUL2R	2.58	1.027	.0
QUL3	3.59	.726	3.8
QUL4	3.68	.728	1.9
QUL5	4.09	.405	.0
S1R	3.09	1.096	.0
S2	3.75	.853	.0
S3	4.02	.747	.0
S4	4.15	.864	.0
S5	4.23	.800	.0
S6	3.94	.602	.0
S7R	3.98	.720	.0
S8R	3.68	.826	.0
S9	4.32	.547	.0

Finally, all negatively worded items were reversed coded as follows: 1 = 5, 2 = 4, 3 = 3, 4 = 2, and 5 = 1. Thirteen new reversed items were created and are denoted by a capital "R" at the end of their labels.

Sample characteristics. Fifty-three ICU nurses completed the survey. Most participants were white women, and the average participant age was 40 years (SD = 9), with a minimum age of 27 years and a maximum age of 60 years. Twenty-two ICU nurses from the medical ICU and 31 ICU nurses from the cardiac ICU completed the survey. The average years of experience as an ICU nurse was 13.17 (SD = 9), with a minimum of 3 years' experience and a maximum of 37 years' experience. This spread of ICU experience indicates that the data were collected from both novice and expert ICU nurses. Similarly, the average CRRT years of experience was 10 years (SD = 7), with a minimum number of years of CRRT experience of one year (novice CRRT users) and a maximum of 31 years (expert CRRT users). Table 4.4 provides a summary of the sample characteristics.

Table 4.4.

Pilot study sample demographics

Sample characteristics	N	Mean (SD) or %
Age	51	40.33 (9)
Gender	53	
Male	18	34%
Female	35	66%
Race/ethnicity	51	
White	42	82%
Hispanic	1	2%
Asian	5	10%
Native Hawaiian/Pacific Islander	1	2%
Multiple races	2	4%
ICU type	53	
Medical ICU	22	42%
Cardiac ICU	31	58%
RN years of experience	52	14.74 (9)
ICU years of experience	52	13.17 (9)
CRRT years of experience	52	9.7 (7)
How often have you managed CRRT in the past year?	53	8.6 (5)
How long have you worked in your current ICU?	53	10 (6.5)
Highest educational degree	53	
Associate	7	13%
BS/BSN/BA	46	87%
Which shift do you work usually?	53	
Day shift	29	55%
Night shift	24	45%
When during the week do you typically work?	52	
Weekdays	8	15%
Weekends	3	6%
Both	41	79%

Reliability. Cronbach's alpha, a measure of internal consistency, was used to test the new instrument's reliability. By assessing the Cronbach's alpha, I examined how closely the items as a group are related. The instrument's Cronbach's alpha (54 items) was 0.843, which is considered adequate. For a new instrument, a Cronbach's alpha higher than 0.7 is considered acceptable (DeVallis, 2003). The Cronbach's alphas for each subscale were also examined and are summarized in Table 4.5. Two subscales, CRRT machine and support, had Cronbach's alphas higher than 0.7, while the other subscales, including the outcomes subscales, had notably poor Cronbach's alphas ranging between -0.148 and 0.465. These scores may be due to the small sample size. Since the sample had only 53 participants, I focused on assessing the internal consistency of the overall scale. Because of the pilot study's small sample size, it was not possible to perform further tests such as factor analysis.

Table 4.5

Cronbach's alphas for each subscale (dimension)

Subscale	N of Items	Cronbach's alphas
CRRT machine	9	0.774
Structure and physical layout	5	0.202
Patient condition and family education	4	0.465
Support	7	0.790
Role definition and communication	3	0.565
Workload	4	0.285
Training, competency, and knowledge	5	0.328
Performance	3	0.417
Quality	5	-0.148
Safety	9	0.451

Revising the Survey and Administering it to a National Sample

All 54 items were tested in the national sample study. Two items were added to the demographic section. The first question asked the participant to provide the state in which he or she was currently practicing nursing, and the second question asked if participants managed CRRT solely or collaboratively with dialysis nurses (Appendix 11).

The participants (n = 308), recruited nationally, completed the instrument administered via REDCap between August 24, 2018 and November 28, 2018. The data were exported into SPSS 25 and assessed for data missingness and outliers. The data missingness rate was less than 8%, and the missing pattern was found to be completely random, as a Little's MCAR test was not significant (Chi-square = 1285.856, DF = 1426, Sig. = 0.997). Therefore, I used the expectation-maximization imputation method with the national study sample to replace missing values.

All negatively worded items were reversed coded as follows: 1 = 5, 2 = 4, 3 = 3, 4 = 2, 5 = 1. Thirteen newly reversed items were created and are denoted by a capital “R” at the end of their labels.

Sample characteristics. Intensive care unit nurses (n = 308) from 39 states in the US completed the survey. Most participants were from Oregon (18%), California (10%), and Texas (6%). Participants were mostly white women, and the average participant age was 42 years (SD = 12), with a minimum age of 22 years and a maximum age of 69 years. The average years of experience as an ICU nurse was 13.32 (SD = 10), with a minimum of one year and a maximum of 40 years. Similar to the pilot study sample, the ICU years of experience range indicates that data were collected from both novice and expert ICU nurses. The average CRRT years of experience was 8.45 years (SD = 7), with a minimum of one year of CRRT experience (novice

CRRT users) and a maximum of 32 years (expert CRRT users). Table 4.6 provides a summary of the sample characteristics.

Table 4. 6

National study sample demographics

Sample characteristics	N	Mean (SD) or %
Age	284	42 (12)
Gender	284	
Male	49	17%
Female	235	83%
Race/Ethnicity	284	
White	239	84%
African American	2	.7%
Hispanic	11	4%
Middle Eastern and North African	1	.4%
Asian	16	5.6%
American Indian/Alaska Native	2	.7%
Native Hawaiian/Pacific Islander	1	.4%
Multiple races	12	4.2%
Teaching hospital	284	
Yes	171	60%
No	113	40%
Hospital location	285	
Rural area	37	13%
Urban area	248	87%
Type of CRRT machine	284	
PrismaFlex (Baxter Medical)	185	65%
NxStage System One (NxStage Medical)	89	31%
Other	10	4%
RN years of experience	275	15.40 (11)
ICU years of experience	279	13.32 (10)
CRRT years of experience	274	8.45 (7)
How often have you managed CRRT in the past year?	267	11.04 (15)

Table 4.6

National study sample demographics (continued)

Sample characteristics	N	Mean (SD) or %
How long have you worked in your current ICU?	143	11.10 (10)
Highest educational degree	284	
Associate	39	14%
BS/BSN/BA	199	70%
MS/MSN	45	16%
DNP/PhD	1	.4%
Which shift do you work usually?	285	
Day (first shift)	175	61%
Evening (second shift)	6	2%
Night (third shift)	104	37%
When during the week do you typically work?	284	
Weekdays	31	11%
Weekends	16	5%
Both	223	84%

Assessing Reliability and Validity

After cleaning and checking the data, I conducted an EFA to construct a multidimensional scale using the individual items created for this study (54 items). Exploratory factor analysis involves four steps: 1) assessment of data suitable for factor analysis, 2) extraction of factors, 3) rotation of factors, and 4) interpretation and labeling (Wiliams, Brown & Onsman, 2010).

Assessing data suitability for the factor analysis was established by examining the sample size, sample-to-variable ratio (*N:P* ratio), factorability of the correlation matrix, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity. The literature includes various sample size recommendations for factor analysis. For example, Comrey and Lee's (1992) guidelines for sample sizes are 100 = poor, 200 = fair, 300 = good, 500

= very good, and 1,000 or more = excellent. Tabachnick (2007) has suggested having at least 300 cases for factor analysis. Considering both Comrey and Lee's and Tabachnick's recommendations, this study's sample size of 310 is considered between fair and good.

Another criterion for assessing the data's suitability for factor analysis is the *N:P* ratio. As is the case with sample size recommendations, there are various guiding principles for the *N:P* ratio. Note that *N* refers to the number of participants and *P* refers to the number of variables (items). In the literature, recommendations include 3:1, 6:1, 10:1, 15:1, and 20:1. With 310 participants and 54 items included in this study, the *N:P* ratio is between 5:1 and 6:1. However, Hogarty et al. (2005) have stated that there is no minimum level of participants or minimum *N:P* ratio for achieving a credible factor analysis.

The next step was to assess the correlation matrix's factorability. This assessment can be achieved by evaluating correlation values. Correlations must be greater than 0.3 but no more than 0.8. Examining the correlation matrix produced from this data set revealed multiple correlations greater than 0.3, and no correlation was found to be higher than 0.8. In addition, the factorability of a correlation matrix can be assessed by examining the determinant of a matrix. The value of the determinant of a correlation matrix ranges between 0 and 1.00. A value of 0 means there are highly correlated items, and a value of 1 means multiple items are uncorrelated and that there are as many factors as there are items. A good determinant value is close to zero. In this data correlation matrix, the determinant was 0.004, which is acceptable. Based on the correlations and correlation matrix determinant, I deemed the matrix factorable.

Finally, I performed tests to measure sample adequacy: the KMO measure of sampling adequacy, individual measures of sampling adequacy (MSA), and Bartlett's test of sphericity. The KMO index and MSA range from 0 to 1. Values of 0.6 or greater are considered suitable for

factor analysis. Additionally, Bartlett's test of sphericity should be significant ($p < 0.05$) for factor analysis to be suitable. Kaiser (1974) has suggested the following criteria for evaluating measures of sample adequacy:

- Above 0.90 is “marvelous”
- In the 0.80s is “meritorious”
- In the 0.70s is “middling”
- Less than 0.60 is “mediocre,” “miserable,” or “unacceptable.”

In this data set, the KMO was 0.791, and Bartlett's test of sphericity was significant (Table 7). However, a few items had low individual MSAs in the anti-image correlation matrix (i.e., lower than 0.60), and therefore, these items were removed. Based on the criteria of data set suitability, I concluded that the data set for this study was suitable and that the initial extraction process could proceed.

Table 4.7

KMO and Bartlett's test results

Kaiser-Meyer-Olkin measure of sampling adequacy.		0.798
Bartlett's test of sphericity	Approx. Chi-square	5244.758
	df	1431
	Sig.	0.000

The second step was to determine the extraction method. There are several extraction methods commonly used in factor analysis. In this study, the goal was to perform EFA to compare the factors developed from phase one with the preliminary factors solution resulting from this data set. Therefore, PCA, which is commonly used with EFA, was used for factor extraction. Notably, PCA uses all variance in the observed variables (items) when extracting factors.

It is desirable when rotating factors to a find simple (parsimonious) and easily interpretable factors solution while keeping the number of factors and communalities of each variable fixed. There are two rotations to use with factor analysis: orthogonal (varimax) and oblique (direct oblimin and promax). Orthogonal rotation produces factors that are uncorrelated with each other, while oblique rotation allows factors to correlate. Both rotations were used in this analysis. However, based on the factor correlation matrix produced by oblique rotations, orthogonal factor rotation results are reported for factor correlations greater than 0.30.

Several factor solutions were examined before selecting the appropriate number of factors. The following criteria (Kim & Mueller, 1978) were used to determine the appropriate number of factors in the retained solution: 1) Kaiser's criteria (eigenvalue > 1 rule), 2) a scree plot, and 3) the cumulative variance explained by the factor solution. Principal component analysis with a Promax rotation was used to reach a simple factors solution. Both Kaiser's rule (Table 4.8) and the scree plot (Figure 4.2) suggested extracting six factors.

Table 4.8

Total variance explained

	Initial eigenvalues			Extraction sums of squared loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.367	21.834	21.834	4.367	21.834	21.834
2	2.184	10.920	32.754	2.184	10.920	32.754
3	1.841	9.206	41.960	1.841	9.206	41.960
4	1.460	7.300	49.260	1.460	7.300	49.260
5	1.232	6.158	55.418	1.232	6.158	55.418
6	**1.090**	5.448	60.866	1.090	5.448	**60.866**
7	**.868**	4.341	65.207			

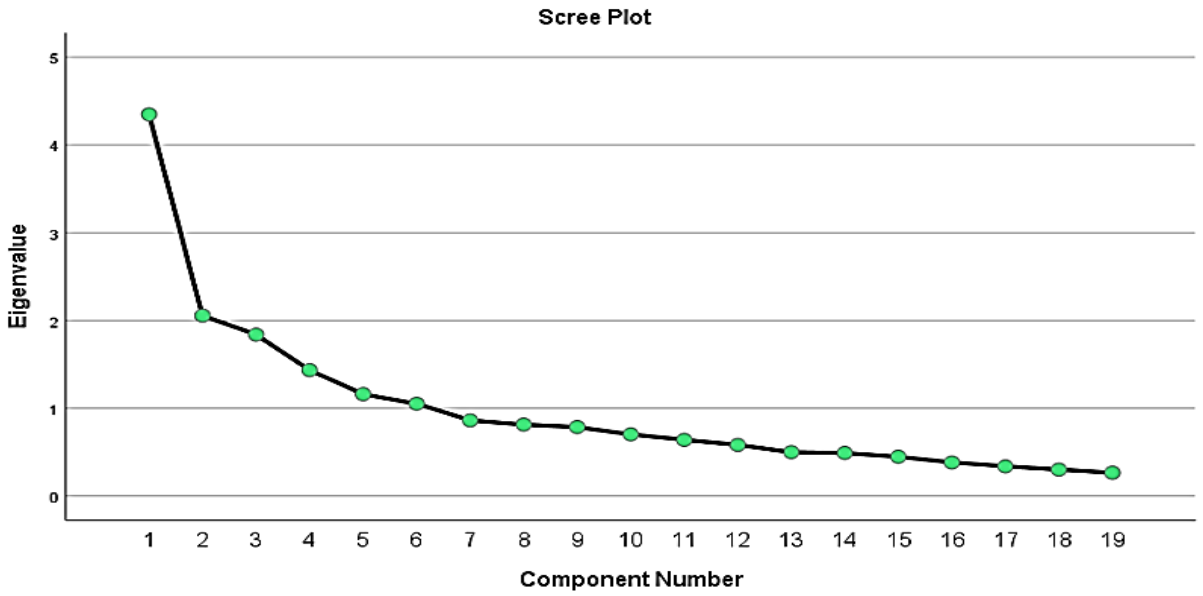

Figure 4.2. Scree plot.

Item communalities were all above 0.3 and less than 0.8. Low communality means there is no shared variance between items, and high communality indicates collinearity. The cumulative variance explained by the six-factor solution (61%) was satisfactory (Table 4.8). Table 4.9 summarizes the six-factor solution and items communalities.

The final step in factor analysis is interpreting and labeling factors. The six factors provided an interpretive solution. Items 7–9 and item 44 loaded heavily on factor 1, which can be interpreted as "CRRT machine technicality." Item 1 and items 3–6 loaded heavily on factor 2. Factor 2 can be interpreted as "CRRT machine functionality." Items 20–22 and item 30 loaded heavily on factor 3, which can be interpreted as "staffing and support." Items 25, 27, and 28 loaded heavily on factor 4, which can be interpreted as "communication and coordination." Items 49 and 50 loaded heavily on factor 5, which can be interpreted as "safeguarding." The final factor, number 6, contains items 35 and 36, which can be interpreted as "training."

After interpreting and labeling the factors, I assessed the internal consistency of each factor. The CRRT machine technicality scale had a Cronbach's alpha of 0.750, the CRRT machine functionality scale had a Cronbach's alpha of 0.694, the staffing and support scale Cronbach's alpha was 0.721, the communication and coordination scale had a Cronbach's alpha of 0.629, the safeguarding scale had a Cronbach's alpha of 0.767, and finally, the training scale had a Cronbach's alpha of 0.557. Nunnally (1978) has suggested that a reliability value of 0.7 or above is acceptable, but other authors have argued that a lower alpha can also be acceptable (Aäronson et al., 1987). Three scales of six had acceptable reliability scores, while the remaining three were lower than 0.7. However, due to the importance of these items in the context of CRRT and the ICU work environment, the decision was made to keep all items and use the new scales in future analyses. The overall Cronbach's alpha for the 20 items was 0.794, which is acceptable. Although this overall Cronbach's alpha could have been slightly improved to 0.795 if item 21 was removed, the decision was made to keep this item since the increase in Cronbach's alpha was not substantial.

Table 4.9

Summary of the factor analysis of the six-factor solution (rotated matrix)

	Components						
	1	2	3	4	5	6	Com*
9- I often encounter technical problems when using the CRRT machine	**.744**	.099	-.042	.124	.099	-.027	.591
8- CRRT filters frequently clot	**.728**	.023	-.031	.067	.139	.006	.556
44- It is easy to run CRRT with minimal down time	**.618**	.180	.183	-.007	.055	.123	.466
7- Setting up the CRRT machine takes a great deal of time	**.615**	.228	.103	.031	-.091	-.089	.459
5- I can easily read the data from the CRRT machine display screen	-.009	**.731**	-.135	.311	.047	.216	.699
6- The display screen on the CRRT machine is well lit and clear	.035	**.672**	-.104	.350	.138	.027	.606
3- The CRRT machine has clear instructions for set-up	.238	**.659**	.295	-.006	-.099	.039	.589
1- The CRRT machine is easy to operate	.420	**.635**	.171	-.047	-.050	.131	.630
4- The CRRT machine has clear instructions for troubleshooting	.324	**.550**	.066	.000	.093	.051	.489
20- There is always another CRRT-trained nurse available to support me during my shift	.072	.057	**.792**	.171	.108	.043	.679
30- There is always a CRRT-trained nurse available to relieve me for breaks	.205	-.014	**.764**	.234	.148	.008	.702
22- The charge nurse is CRRT-trained and helps me when needed	.021	.018	**.722**	.154	-.021	.124	.562
21- Other nurses help me when managing CRRT	-.341	.280	**.517**	-.140	.276	.015	.512
27- It is clear which provider I need to contact regarding CRRT notifications and questions	.012	.215	.081	**.787**	-.009	.059	.676
28- I can reach the on-call physician to report changes in my patient's condition at any time	.009	.059	.231	**.682**	-.017	.070	.527
25- It is easy to coordinate with other departments to ensure there is an adequate supply of fluid bags and medications	.171	.046	.155	**.620**	.041	.102	.452
50- We always have two nurses double check medication orders related to CRRT prior to administration	.105	-.023	.043	-.060	**.881**	.048	.795
49- I always have another CRRT-trained nurse to check CRRT orders and settings with me prior to initiation	.092	.089	.203	.103	**.852**	.015	.795
36- The more I practice CRRT, the easier it gets	.043	.075	.120	.045	-.026	**.847**	.743
35- Using a CRRT machine for a hands-on practice during the CRRT training course was helpful	-.030	.168	.040	.181	.092	**.760**	.650
Variance (%)	**21.8%**	**11%**	**9.2%**	**7.3%**	**6.2%**	**5.4%**	----

* Com = Communality

The second part of the instrument developed for this study, the "satisfaction scale," considered satisfaction with performance, quality of care, and patient safety. The same four steps discussed earlier in the context of the EFA were followed to develop the outcomes scale. A PCA yielded one factor, based on the eigenvalue and scree plot, with acceptable KMO and Bartlett's test scores. The total variance explained by this scale was 67.3%, which is also acceptable. The satisfaction scale had an acceptable Cronbach's alpha of 0.751. Additionally, the satisfaction scale significantly correlated with the new scale ($r = 0.519$, $p < 0.01$).

Confirming the Final Structure of the New Instrument

The final structure of the CRRT practice instrument has six subscales with a total of 20 items and one outcome scale with three items (see Appendix 12). The following section describes the descriptive statistics performed for the six subscales, the total score, and the satisfaction scale score. Additionally, a correlation analysis was carried out to assess construct validity.

Descriptive analysis and correlations. This section reports the descriptive statistics and correlation analysis results. Before I ran these statistical tests, composite scores for each subscale and the total score were created as an index with the scores ranging from 0 to 100 so the results could be easily reported and interpreted.

The ICU work environment and CRRT practice. In this sample of 308 ICU nurses, most highly rated the CRRT machine functionality. Almost 80% described the CRRT machine as easy to operate, 70% said that the machine provides clear instructions during setup and troubleshooting, 95% stated that it is easy to read data from the display screen, and 95% said the display screen is well lit. The average score for machine functionality was 75.92 (SD = 14.8), indicating that ICU nurses experience less issues operating the CRRT machine.

Regarding technical issues while managing the CRRT machine, 40% said setting up the machine takes time, 45% reported that the filter clots frequently, and 25% stated that they encounter technical problems when using the CRRT machine. The average score for machine technicality was 51 (SD = 16.7), meaning the ICU nurses had experienced some technical problems with the CRRT machine.

Staffing and support are crucial for managing a high-risk, highly demanding therapy like CRRT. The majority of participants said that they receive help from other CRRT-trained ICU nurses (72%) and from other ICU nurses (79%). Most also said that their charge nurse is CRRT-trained and available to help when required. While the majority said that they receive significant support from other ICU nurses, only 58% said that they have another CRRT-trained ICU nurse available to relieve them during a break. For the staffing and support scale, the average support ICU nurse score was 67.30 (SD = 18.1), meaning the ICU nurses adequate staffing and support when managing CRRT.

Communication and coordination are crucial in CRRT management. Seventy-two percent of participants said it is easy to coordinate supplies delivery with other departments, and 85% of the ICU nurses clearly know whom to contact when reporting CRRT outcomes and can easily contact the on-call physician to report changes in a patient's condition. The average score for communication and coordination was 75 (SD = 15.5), meaning the ICU nurses had experienced less issues with communication and coordination around CRRT.

Safeguarding strategies ICU nurses follow to ensure safe practice were, interestingly, different in this sample. While 68% said they double-check CRRT orders before connecting a patient to the CRRT machine, only 46% stated that they double-check medication and fluid orders with another CRRT-trained nurse before administration. This finding could mean that

different institutions have different policies for safeguarding patients. The average safeguarding score was 61.6 (SD = 26.4).

The final subscale is training. Ninety percent of the ICU nurses highly appreciated the hands-on part of their CRRT training, and 96% had become more confident in managing CRRT over time. The average score for training was 84.17 (SD = 13.5).

Table 4.10

CRRT practice descriptive statistics

	N	Minimum	Maximum	Mean	SD	95% CI
Machine functionality	308	5.00	100.00	75.92	14.8	74.26 – 77.58
Machine technicality	308	6.25	87.50	50.91	16.7	49.03 – 52.78
Staffing and support	308	6.25	100.00	67.32	18.1	65.29 – 69.35
Communication and coordination	308	.00	100.00	74.99	15.5	73.26 – 76.73
Safeguarding	308	.00	100.00	61.65	26.4	58.69 – 64.61
Training	308	37.50	100.00	84.17	13.5	82.65 – 85.69
CRRT total	308	30.26	97.74	68.82	10.5	67.66 – 69.97

The average overall score of the new scale was 68.82 (SD = 10.50), indicating that the ICU nurses experience few issues in their ICU work environment when managing CRRT. Table 4.10 summarizes the new scale descriptive statistics.

Workload and CRRT practice. The NASA-TLX was used to assess the ICU nurses' perceived workloads associated with CRRT. Participants scored high in mental demand and effort items, meaning CRRT is a complex and highly demanding task. CRRT management requires high mental and perceptual activities, and ICU nurses must work hard mentally and physically to achieve their level of performance. However, the ICU nurses reported that their performance is strong and that they are satisfied with their performance. While the complexity

and the physical and mental demand were high concerning CRRT, frustration scores were average. However, the overall score for workload was high. Table 4.11 summarizes the NASA-TLX scale results.

Table 4.11

NASA-TLX descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation	95% CI
Mental demand	308	0	100	83.33	15.7	81.57 – 85.09
Physical demand	308	2	100	74.53	18.7	72.43 – 76.63
Temporal demand	308	1	100	70.75	19.2	68.60 – 72.90
Effort	308	29	100	79.47	15.6	77.72 – 81.21
Performance	308	2	100	85.67	12.6	84.26 – 87.09
Frustration level	308	0	100	50.18	26.8	47.17 – 53.19
RTLX*	308	27.17	97.00	74.00	11.5	72.70 – 75.27

*RTLX references to rated TLX total (not weighted)

Correlations between the new scale and NASA-TLX scale. The results revealed that the new scale was inversely correlated with the RTLX. That is, when ICU nurses encounter fewer issues in their ICU work environment, their CRRT management performance improves and workload decreases ($r = - 0.262$, $p < 0.01$).

Summary

This chapter has reported a CRRT practice grounded theory and has focused on describing the dimensions of the ICU work environment that impact CRRT practice, ICU nurses' performance, quality of care, and patient safety. These dimensions (factors) are CRRT machine functionality, CRRT machine technicality, the ICU physical environment, patient and family needs, support, communication and coordination, role definition, workload, and training. Based on these identified dimensions, the New scale was developed with 54 items. The new scale was

pilot tested and retested with a national sample. Exploratory factor analysis was performed using PCA and oblique rotation. A six-factor solution resulted from the EFA, and the New scale was reduced to 23 items. Twenty items measure machine functionality, machine technicality, safeguarding, staffing and support, training, and communication and coordination. The overall Cronbach's alpha was 0.805, and the subscales' alphas ranged between 0.553 and 0.770. The new scale inversely correlated with the NASA-TLX and positively correlated with the CRRT satisfaction scale. The significant correlation between the New scale and the NASA-TLX scale provides evidence of convergent validity for the new instrument.

CHAPTER FIVE

Discussion of the Findings

The specific aims of this study were to 1) describe the impact of the ICU work environment on CRRT nursing practice and ICU nurses' performance, quality of care, and patient safety; 2) identify ICU nurses' perceptions of factors in the ICU work environment that influence their performance when managing CRRT and affect quality and safety outcomes; 3) generate a substantive grounded theory of the ICU work environment and CRRT nursing practice; and 4) develop and test an instrument to measure the perceived impact of the ICU work environment on CRRT nursing practice, quality of care, and patient safety.

The purpose of this chapter is to discuss the findings from this study and situate them in the current knowledge base. In addition, this chapter includes an evaluation of the ICU work environment and CRRT practice theory and the new instrument, *the Nurse's ICU-CRRT Environment (NICE) Scale*. The chapter concludes with a discussion of the study's limitations and strengths and by considering implications for future practice and research.

The ICU-CRRT Practice Theory

The ICU-CRRT practice model was developed using DA. Seventeen interviews were conducted with 14 ICU nurses who worked full-time, had more than one year of work experience in the ICU, and had at least minimally managed CRRT twice in the past six months.

The ICU-CRRT practice theory focuses on the CRRT nursing care process. The process of CRRT nursing care is a multidimensional dynamic process that results from ICU nurses' interactions with their ICU environment, the nurse-CRRT machine interface, and nurses' attainment to patient and family needs. This process is motivated by the desire to ensure quality of care and patient safety.

The ICU as a Working Environment

Characteristics of ICUs. The ICU environment is considered demanding and stressful; ICU nurses must respond continuously and quickly to the critical needs of patients and patients' families, perform procedures accurately, and coordinate care with other healthcare providers (Gurses & Carayon, 2007; Gurses et al., 2009; Reis Miranda & Jegers, 2012). It is generally known that factors related to the elements of the ICU work environment—such as teamwork and collaboration, coordination, communication, complexity of tasks and workload, and physical environment—can influence performance, patient safety, and quality of care (Gurses & Carayon, 2008, 2007; Gurses et al., 2009).

In this study, factors related to the ICU work environment perceived to impact CRRT practice were consistent with the literature. These factors are the physical environment (patient room, unit size and layout, noise, and supplies accessibility), communication, staffing, support, workload, and team role definition.

Physical environment. ICU nurses believe that small patient rooms can make maneuvering and situating a CRRT machine difficult. ICU nurses may need to shift equipment locations to place a CRRT machine near the patient, which can take some time. Noises coming from equipment alarms in the room, in addition to alarms from the CRRT machine, and the hourly routine of ICU nurses entering the patient room to check CRRT pressures can interrupt a patient's sleep. The literature has demonstrated that patients experience poor sleep quality and consistently report poor perceived sleep quality in the ICU as compared to at home (Bani Younis & Hayajneh, 2018; Kamdar, Needham, & Collop, 2011; Romero-Bermejo, 2014). Additionally, surveys of ICU survivors have demonstrated that sleep deprivation and the inability to sleep rank

among the top three major sources of anxiety and stress during an ICU stay, along with pain and intubation (Gupta et al., 2018; Kamdar et al., 2011; Novaes et al., 1999).

ICU nurses reported needing to keep CRRT-related supplies in the patient room. Although this practice can make a patient's room crowded, it makes it easy for ICU nurses to see how much fluid they need to stock to cover 24 hours of CRRT. ICU nurses must be able to access supply rooms quickly to collect additional supplies. Therefore, the layout of an ICU is arguably the most important design feature affecting all aspects of critical care services (Anderson & Halpern, 2016). While patients' room designs are central to ICU design, it is crucial to bind the patient rooms and other support areas for the overall goal of supporting bedside care (Anderson & Halpern, 2016; Thompson et al., 2012).

Communication and team role definition. Improving communication in clinical areas is a national and international patient safety goal (Miller et al., 2009). Thirty-seven percent of errors are associated with nurse-physician communication (Reader et al., 2007, 2009). Therefore, clear and open communication is critical to eliminate errors.

Communication of CRRT orders appeared in this study as written protocols the nephrology team writes once the decision to start a patient on CRRT is made. The findings revealed that the clarity of CRRT protocols help ICU nurses in their work and guide them as they implement needed interventions based on patients' blood test results and responses to CRRT. The protocols guide ICU nurses regarding when and what changes in patient conditions must be reported to nephrology. However, the ICU nurses reported that during night shifts, it is difficult to receive a call back from on-call nephrology residents to report changes in patients' conditions related to CRRT. Therefore, the inability of ICU nurses to reach an on-call nephrology resident during night shift is problematic.

Furthermore, clear role definitions for each team member involved in CRRT management yields better communication. In this study, the ICU nurses stated that intensivists refer a patient to the nephrology team once a need for renal support arises. The nephrology team assesses a patient's condition, orders CRRT if needed, and reviews the patient's response to CRRT on a daily basis. This clarity of role definitions makes it easy for the ICU nurses to understand whom to contact to report changes in a patient's condition related to CRRT.

Staffing and support. Administration ensures proper coverage of the unit with enough staff to safely manage CRRT. In this study, ICU nurses stated that once CRRT is added to a patient's care plan, the nurse-patient ratio changes from 1:2 to 1:1 immediately. As suggested in the literature, for a standard 12-hour shift, the staffing ratio with CRRT is 1:1 (Graham & Lischer, 2011). Furthermore, the ICU nurses said any in-charge nurse has to be CRRT-trained to ensure adequate support for ICU nurses when help with the CRRT machine is needed. If the complexity of a patient's care increases, the staffing ratio changes to 2:1. It is not necessary that the added ICU nurse be CRRT-trained. The work is then divided into two parts: CRRT care and all non-CRRT-related care.

The ICU nurses shared that they receive a great deal of support when managing CRRT. In this study, support was described as human support and material support. Human support is the support ICU nurses receive from colleagues, nurse managers, charge nurses, nurse educators, ICU nurses from other units, and dialysis nurses. Material support is the support related to the availability of resources, including P&P manuals, manufacturing manuals, and CRRT binders attached to CRRT machines including step-by-step instructions and guidelines.

Workload. The ICU nurses believe that adding CRRT to a patient's care plan significantly increases their workload. Of note, workload is one of the most important

determinants of patient safety and quality of care in the ICU (Gurses & Carayon, 2007, 2008). High workload and insufficient staffing levels are associated with drug administration and documentation problems, inadequate patient supervision, incorrect setup of ventilators and equipment, and self-extubation incidents (Dougherty & Larson, 2010). Therefore, this study found that due to the increased workload, the staffing ratio changes to 1:1 when CRRT is added, as mentioned earlier. However, it is unknown if this ratio is standard practice across ICUs nationally and internationally.

The CRRT Machine

CRRT Machine evolution. Since CRRT was first used in the 1960s, specific machines have been designed to ensure the safe and reliable performance of therapy (Clark et al., 2017; Ronco, 2017). Over time, CRRT machines have undergone a series of technological improvements, resulting in the highly sophisticated equipment used today (Ronco, 2017). Modern CRRT machines were described by the participants as user-friendly and easy to operate. Due to the high risk associated with CRRT and the multiple, yet straightforward and simple, steps that must be followed when setting up the machine, the ICU nurses said that they had felt nervous initially but became more confident over time. The characteristics of the CRRT machine, as described by the ICU nurses, are its size, portability, ease of operation, user-friendliness, size and clarity of display screen, and filter and filter life. These characteristics make the ICU nurses more comfortable and confident when managing CRRT. Despite the positive characteristics of modern CRRT machines, there are serious efforts underway to "down-size" this technology (Clark et al., 2017; Ronco, 2017). Decreasing the physical size of medical technologies to the point of creating a wearable and miniaturized artificial kidney should

enhance portability and extend the use of CRRT technology to more patients and care settings, including home therapy (Clark et al., 2017; Ronco, 2017; Ronco et al., 2008).

Training and competency. Optimal CRRT delivery relies on expert bedside ICU nurses to maintain the prescribed therapy, troubleshoot technical issues, and ensure patient safety. Therefore, ICU nurses need specialized knowledge and skills to manage the added responsibilities (Baldwin & Fealy, 2009; Kleger & FäSsler, 2010; Mottes et al., 2013; Schell-Chaple, 2017). The ICU nurses in this study reported that the CRRT training they had received had prepared them well to manage CRRT. However, CRRT training remains unstandardized nationally and internationally, with each institution developing its own CRRT training program (Baldwin & Fealy, 2009; Graham & Lischer, 2011; Przybyl et al., 2017). Przybyl et al. (2017) suggests that adult learning principles should be considered and incorporated to have a successful CRRT training. Furthermore, a variety of teaching methods, including online learning modules, didactic lecture, return demonstration, and high-fidelity patient simulation are key to training programs for this high-risk complex therapy.

Likewise, there are no universal competencies for CRRT, and each institution develops its own policies for maintaining CRRT competency to ensure safe practice (Baldwin & Fealy, 2009; Golestaneh et al., 2012; Graham & Lischer, 2011; Langford et al., 2008; Przybyl et al., 2017). In this study, participants reported a minimum requirement of five patient care days to maintain CRRT competency. That is, CRRT-trained ICU nurses have to be assigned to CRRT patients often enough throughout the year to maintain their competency. Therefore, maintaining CRRT competency is dictated by the unit's number of CRRT cases per year (Golestaneh et al., 2012; Martin, 1997). The findings also show that the number of CRRT cases per year is affected by ICU type. That is, the frequency of having patients on CRRT varies based on the type of ICU.

For example, in the medical ICU, nurses encounter CRRT more frequently than do nurses in the cardiovascular ICU.

Proper training and maintenance of competency contribute to the process of "knowing what to do," which was identified by the ICU nurses in this study. Knowing what to do is a process in which ICU nurses act effectively and safely when managing CRRT. Intensive care unit nurses must know how to closely and competently monitor the patient's fluid volume, laboratory values (electrolytes levels, acid-base status, and blood components), fluid removal goals, anticoagulation therapy, venous catheter site and function, and hemodynamic status (Cruz et al., 2010; Liu et al., 2014; Schneider & Bellomo, 2013). It is expected that ICU nurses know how to calculate hourly fluid removal and adjust the rate accordingly, recognize signs of filter clotting or clogging, and return blood to the patient when treatment is discontinued or before filter changes.

Coordinating supplies. "Staying on top of things" is another process the ICU nurses reported experiencing when managing CRRT. The process of staying on top of things requires a great deal of team coordination. According to Klein (2001), team coordination is

> "the attempt by multiple entities to act in concert in order to achieve a common goal by carrying out a script/plan they all understand." (p.71)

The goal of staying on top of things is to successfully and continuously run CRRT. Interrupting this process can lead to an interruption of CRRT. For example, to ensure the availability of enough supplies, ICU nurses have to anticipate the number of fluid bags needed to continue running CRRT and coordinate with the pharmacy to prepare and deliver fluids bags to the unit a head of time.

Errors and adverse events. CRRT is considered a high-risk therapy with serious potential complications, and therefore, ICU nurses must closely monitor their patients to identify and manage these complications. Among these complications are vascular access-related complications (infection, bleeding, thrombosis, arteriovenous fistula formation, hematoma, aneurysm formation, hemothorax, pneumothorax, pericardial tamponade, and air embolism), circuit-related complications (air embolism, reduced filter life, reduced dialysis dose, hypothermia, bio-incompatibility, immunologic activation, and anaphylaxis), hematologic complications (bleeding, hypocalcemia, citrate intoxication, hemolysis, and heparin-induced thrombocytopenia), acid-base imbalance, electrolyte imbalance, poor glycemic control, and hemodynamic instability (Deepa & Muralidhar, 2012; Finkel & Podoll, 2009; Rimmelé, 2018).

Due to the high risks associated with CRRT, ICU nurses follow a process of safeguarding patients when caring for a patient on CRRT. Safeguarding patients is enacted to ensure safe practice while managing CRRT. ICU patients who require CRRT experience a high incidence of adverse events (Akhoundi et al., 2015; Maynar Moliner, Honore, Sánchez-Izquierdo Riera, Herrera Gutiérrez, & Spapen, 2012). Among these adverse events are electrolyte derangements (hypocalcemia, hypercalcemia, and hyperphosphatemia), hypotension within the first hour after CRRT initiation, hypothermia, arrhythmias, anemia, and thrombocytopenia. Although the extent to which these complications are attributable to CRRT is unknown, ICU nurses must be cautious and aware of the high prevalence of adverse events in this patient population. Furthermore, the incorrect use or failure of complex equipment, such as the CRRT machine, can potentially harm a patient. Thomas and Galvin (2008) found that, in this context, errors related to dialysis machines in the ICU are the third most common issue after syringe pumps and ventilators. Specifically, 42% of errors associated with dialysis machines were related to incorrect use, faulty

equipment, and failure of equipment (Thomas & Galvin, 2008). However, it is not clear if Thomas and Galvin's study included CRRT machines.

Starting a Patient on CRRT

Patient characteristics and family needs. One in five critically ill adults experiences AKI during a hospital episode of care (US Renal Data System, 2018). The rate of developing AKI increases with advanced age and in African Americans (US Renal Data System, 2018). In addition to advanced age and race, other risk factors for developing AKI are diabetes mellitus, heart failure, liver failure, chronic kidney disease, hypotension, and sepsis (Rahman, Shad, & Smith, 2012). Patients who undergo cardiac or vascular surgery, organ transplantation, or mechanical ventilation or who are exposed to contrast media, nonsteroidal-inflammatory drugs, antimicrobial drugs, or chemotherapeutic agents commonly experience AKI as a complicating condition (Bellomo et al., 2004; Brown et al., 2016; Lameire et al., 2013; Rahman et al., 2012). Therefore, patients requiring CRRT to support their kidney function tend to be older, sicker, and with multiple diagnoses. The complexity of patients' conditions can lead to an increase in care and may require additional therapies. Thus, the workload increases of a nurse caring for a patient with AKI and requiring CRRT and additional therapies.

Before starting CRRT for a patient, the medical team describes the situation and the need for CRRT to the patient and his or her healthcare proxies (HCPs). Frequently, patients and HCPs sign a consent form without fully understanding CRRT. Intensive care unit nurses often spend some time addressing this knowledge deficit. Allegretti et al. (2015) assessed patients and their HCPs' level of understanding of CRRT and found that patients and their HCPs may overestimate their level of understanding and may believe that CRRT improves the speed of renal recovery.

Importantly, an accurate understanding of the prognosis and purpose of CRRT allows patients and their HCPs to make informed decisions about care goals.

Late versus early initiation of therapy: a medical decision. For the past two decades, there has been controversy regarding when to start CRRT for a patient. It has been reported that CRRT often starts late for patients. Possible reasons behind a delay in initiating CRRT are a lack of consensus on the definition of AKI and unclear CRRT indication criteria (Acute Kidney Injury Work Group, 2012; Mehta et al., 2007; Shiao, Huang, Spapen, Honore, & Wu, 2017; Vinsonneau & Monchi, 2016). Macedo & Mehta (2011) have proposed a patient-centered approach to defining early and late initiation, which could serve as a framework for managing patients and future studies in this area. The authors have encouraged providers to assess patients for changes in renal function and utilize dialysis to support organ function and prevent complications rather than waiting for complete renal shutdown before initiating CRRT (Macedo & Mehta, 2011). They have also argued that the timing of dialysis initiation is a potentially modifiable factor important for determining patient outcomes in AKI (Macedo & Mehta, 2011). Participants in the present study made the same observation regarding late CRRT initiation for their patients.

Delays in connecting a patient to a CRRT machine. Once a decision is made to start a patient on CRRT, a delay in connecting the patient to a CRRT machine can occur due to delays in priming and preparing a CRRT machine, confirming vascular access placement, or receiving laboratory test results in a timely fashion. In this study, the ICU nurses reported witnessing a change in CRRT nursing management as the management of CRRT shifted from dialysis nurses to ICU nurses. This shift resulted in shortening the time between ordering CRRT and connecting a patient to a CRRT machine since the CRRT machines are stored in each ICU, and ICU nurses

can start priming the machine immediately. The unavailability of ancillary services was identified by the ICU nurses as a cause for delaying CRRT for their patients. Ancillary services involved in CRRT include the radiology department and laboratory.

Comparing the ICU-CRRT Practice Theory to Other Models

Comparing the ICU-CRRT practice theory to Donabedian's SPO model and the SEIPS model reveals some similarities and differences. Unlike the SPO model, the ICU-CRRT practice theory recognizes the interactions and interdependencies among system components (structure), similar to the SEIPS model. The SPO model explicitly and directly links the structure and processes of care to subsequent patient outcomes. In contrast, the SEIPS model has feedback loops between outcome and structure, and process and structure. The ICU-CRRT practice theory also has a feedback loop to the structure (i.e., the patient context) and has a bidirectional arrow runs between structure and process.

Finally, the SPO model's focus is on providers and their relationship with processes and outcomes. The SEIPS model emphasizes the structure of the work environment and interactions among its elements, but the ICU-CRRT practice theory focuses on the providers (ICU nurses), their relationship with the processes and outcomes, and the structure of the work environment and the interactions among its elements.

In summary, the ICU-CRRT practice theory is a work system theory grounded in the context of CRRT practice. This theory describes the process of CRRT nursing care within the ICU work environment and thus differs from other work environment theories because it is specific to CRRT. The theory offers a detailed description of factors in the ICU work environment that have a perceived impact on ICU nurses' performance, quality of CRRT care,

and patient safety. In addition, this theory describes the social processes ICU nurses experience when managing CRRT.

The Nurse's ICU-CRRT Environment (NICE) Scale

The overall purpose of this exploratory sequential mixed-methods study was to measure nurses' perceptions of the impact of the ICU work environment on CRRT practice, performance, quality of care, and patient safety. The qualitative phase produced 15 dimensions: three contexts (the ICU environment, the CRRT machine, and the patient), five conditions (staffing and support, team role definition and communication, training and competency and CRRT frequency, workload, and patient and family needs), four processes (starting a patient on CRRT, safeguarding patients, knowing what to do, and staying on top of things), and three outcomes (performance, quality of care, and safety). These 15 dimensions guided the development of 10 subscales for the Nurse's ICU-CRRT Environment (NICE) Scale.

The items were developed and revised based on committee feedback, expert panel feedback, and the results from the content validity testing (S-CVI/Ave = 0.92). The NICE scale, which contains 54 items, was pilot tested. The overall Cronbach's alpha was 0.843, which is considered adequate. This result means that generally, items are related to each other and to the whole scale. However, the internal consistency reliabilities for seven subscales were very low (α= -0.148–0.451). Possible explanations for this low Cronbach's alpha are the pilot study's small sample size (n = 53), the items measure multiple constructs, and low number of items in these subscales, as Cronbach's alpha is sensitive to the number of items in a scale. As the number of items increases, the Cronbach's alpha increases (DeVellis, 2003). Additionally, more items in a scale mean that the error is equally distributed across items and that the observed construct is equal to the true construct being measured. Since the study had a small sample size, I

decided to keep all 54 items and to proceed to conducting a national study so a factor analysis could be performed on the new instrument and a final number of items can be determined.

Exploratory factor analysis using PCA revealed a six-factor solution with 20 items. These factors were CRRT machine functionality, CRRT machine technicality, staffing and support, communication and coordination, safeguarding, and training. Although the structure of the new instrument did not mirror the theoretical model, the final solution includes, to a great degree, the majority of the dimensions from the ICU-CRRT practice theory. Furthermore, due to reducing the number of items from 54 to 20, some dimensions did not appear in the final solution. For example, the patient and family needs subscale items neither correlated with each other to form a factor nor correlated with other subscales. Therefore, this subscale was removed. However, these items asked crucial questions and will be reevaluated, revised, and retested in future research studies.

The NICE scale appears to be a reliable instrument. Overall scale reliability had a Cronbach's alpha of 0.794, and the Cronbach's alpha scores for the subscales ranged between 0.557 and 0.767. Three subscales had Cronbach's alpha scores below 0.7 (i.e., CRRT machine functionality, $\alpha = 0.694$; communication and coordination, $\alpha = 0.629$; and training, $\alpha = 0.557$). Despite the low alpha scores, these three subscales are important in the ICU-CRRT context. Therefore, all subscales will be kept and used in future research.

Furthermore, there are some existing instruments with low Cronbach's alpha scores, below 0.7, that are considered reliable and valid and that have been used for a long time. For example, the Medical Outcomes Study 36-Item Short Form (SF-36) has been used to evaluates patient-perceived health status across broad physical and emotional health domains. The SF-36 consists of eight multiple-item subscales: physical function, social functioning, role limitations

due to physical problems, role limitations due to emotional problems, mental health, vitality, pain, and general health perception (Ware & Sherbourne, 1992). The Cronbach's alpha scores of the SF-36 subscales are greater than 0.70 for all but the general health ($\alpha = 0.693$) and social functioning ($\alpha = 0.527$) subscales (Bunevicius, 2017). Despite these low Cronbach's alphas, the SF-36 is the most commonly used generic health-related quality of life (HRQoL) tool globally for patients and the general population and has been in use since 1990 (Ware & Sherbourne, 1992).

In an exploratory sequential mixed methods study design, merging qualitative and quantitative results is not typical in instrument design for two reasons. First, merging already occurs when items are created based on qualitative data—one phase builds on the other. Second, the qualitative and quantitative phases usually have different samples for merging the results. However, I was interested in assessing what findings from the initial qualitative phase could be confirmed and generalized to the population by using a survey method in phase two.

Therefore, a side-by-side comparison is provided because it is a common strategy for merged data analysis (Creswell and Plano Clark, 2011). Table 5.1 lists the findings from the qualitative and quantitative phases and compares results with each other.

Table 5.1
Comparing the qualitative findings with the quantitative results

Qualitative findings (n = 14)	**Quantitative findings** (n = 308)		**Comparison**
• The CRRT machine has become easier to set up and operate. • The CRRT machine has a large, bright display to increase the accessibility of information on the screen. • The CRRT machine gives clear and easy-to-follow steps on how to set up the machine or troubleshoot problems.	Machine functionality	Mean = 76 (95% CI = 74–77)	Consistent
• Intensive care unit nurses sometimes experience abrupt clotting of the filter.	Machine technicality	Mean = 48 (95% CI = 46–50)	Consistent
• The nurse-patient ratio changes from 1:2 to 1:1 immediately when CRRT starts. • Intensive care unit nurses receive support for CRRT from other ICU nurses on the unit. • On some occasions, no other CRRT-trained ICU nurses are available during the shift to offer relief for breaks.	Staffing and support	Mean = 67 (95% CI = 65–69)	Consistent
Process: Staying on top of things • Ensuring that adequate CRRT supplies are available in the unit throughout the shift.	Communication and coordination	Mean = 75 (95% CI = 73–77)	Consistent
Process: Safeguarding patients • Before connecting a patient to a CRRT machine, two ICU nurses verify the CRRT orders and match the orders with the CRRT machine settings.	Safeguarding	Mean = 62 (95% CI = 59–65)	Consistent
Process: Knowing what to do • Intensive care unit nurses believe that the hands-on training they received successfully prepared them to operate and troubleshoot a CRRT machine. • The more hands-on experience managing CRRT ICU nurses have, the more confident they feel.	Training	Mean = 84 (95% CI = 83–86)	Consistent

Strengths and Limitations

Like any study, the present study has strengths and weaknesses. A major strength of this study is the approach to inquiry. Mixing and integrating two approaches—qualitative and quantitative—in one study provides a strong breadth and depth of understanding and corroboration.

Phase one was a critical part of this inquiry because no previous qualitative study, to the author's knowledge, has entailed interviewing ICU nurses and giving them the opportunity to talk about their experiences managing CRRT in the ICU work environment. Descriptions of "what all is involved here" regarding CRRT were missing from the literature. Thus, this study identified and defined the dimensions in the ICU work environment that nurses perceive to impacting their CRRT practice, performance, quality of care, and patient safety. Not only did this study identify and define these dimensions but the theoretical connections and relationships among the dimensions were also described and depicted visually. Therefore, this study fills a gap in the CRRT nursing care literature by providing a conceptualization of the effect of the ICU work environment on CRRT.

In phase two, I addressed a need by developing an instrument that is theory-based, grounded in the ICU environment, and appropriate to the context of CRRT to assess the perceived impact of the ICU work environment on CRRT practice, ICU nurses' performance, quality of care, and patient safety.

However, this study was limited to English-speaking ICU nurses who work in adult ICUs, which limits the transferability of the study to non-English-speaking ICUs and neonatal or pediatric ICUs. The use of a convenience sample in both phases also limits generalizability. Additionally, the model and instrument are not specific to one CRRT modality or medical

diagnosis; there is variation between CRRT modalities that require additional tasks. Because prognosis or co-morbid medical diagnoses may impact nurses' workloads, and concomitantly, impact the quality of CRRT nursing practice, use of this measure may not capture work system factors pertinent to patients with special circumstances.

Furthermore, the sample size in both phases was between small and adequate, which could affect the generalizability of the findings. Another limit on the generalizability of the findings is the cross-sectional method applied for collecting data in the pilot study and national study.

Implications

Implications for Practice

The ICU-CRRT practice theory and the NICE scale can guide hospital management teams in assessing factors in the ICU work environment and supporting the development of targeted interventions to support ICU nurses in their practice, promote high-quality care, and ensure patient safety. Importantly, staffing and support are the two factors the ICU nurses cited most frequently in this study. Ensuring adequate staffing by guaranteeing that the nurse-patient ratio is always 1:1 and the availability of other CRRT-trained staff, in addition to the nurse in charge, during a shift can have a substantial impact on performance, quality, and safety.

Implications for Education

CRRT training must be reformed and standardized nationally and internationally. Standardizing training is likely to minimize variability in how CRRT is administered and improve educators' ability to evaluate the quality of training. The ICU-CRRT practice theory could be integrated into a CRRT training program to help ICU nurses prepare for their roles and anticipate how to best manage CRRT.

Implications for Research

The development of the theory and a theory-based instrument constitute major contributions to the CRRT literature. Before this study, no theory had defined the factors in the ICU work environment, their relationships with one another, and the processes that occur when ICU nurses manage CRRT. Additionally, no instruments were available to measure the perceived impact of the ICU work environment on CRRT practice. This study provides a testable instrument and a theoretical model that can be used in future research to further explore the perceived impact of the ICU work environment. The NICE scale can be used as a baseline ICU work environment assessment tool or as a pre- and post-intervention measure in an intervention study.

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Appendices

Appendix 1- Site Approval Letter

OREGON HEALTH & SCIENCE UNIVERSITY

OHSU Healthcare
3181 S.W. Sam Jackson Park Rd.
Portland, Oregon 97239-3098

SITE APPROVAL LETTER

Subject: Site Approval Letter

To whom it may concern:

This letter acknowledges that I have received and reviewed a request by Wafaa BinAli to conduct a research project entitled "Perceived impact of ICU work environment on ICU nurses performance, CRRT practice, quality of care, and patient safety in Adult Intensive Care Units: A Mixed Methods Study" at Oregon Health and Science University Hospital and I approve of this research to be conducted at our facility.

Sincerely,

Judi Workman, MS, RN, NEA-BC
Division Director Cardiovascular/Critical Care Nursing
503-418-3772

Appendix 2 - OHSU IRB Approvals

OREGON HEALTH & SCIENCE UNIVERSITY

IRB MEMO

Research Integrity Office
3181 SW Sam Jackson Park Road - L106RI
Portland, OR 97239-3098
(503)494-7887 irb@ohsu.edu

APPROVAL OF SUBMISSION

November 17, 2016
Dear Investigator:

On 11/16/2016, the IRB reviewed the following submission:

IRB ID:	STUDY00016210
Type of Review:	Initial Study
Title of Study:	Perceived impact of ICU work environment on continuous renal replacement therapy (CRRT) practice, ICU nurses' performance, quality of care, and patient safety.
Principal Investigator:	Dena Hassouneh
Funding:	Name: OHSU School of Nursing, PPQ #: N/A
IND, IDE, or HDE:	None
Documents Reviewed:	Recruitment Email Demographic form.docx Telephone Script Site Approval Letter.pdf Protocol.pdf Bin Ali Dean Award.pdf Interview_Guide_FINAL.doc Information Sheet.pdf Recruitment Flyer.pdf

The IRB granted final approval on 11/16/2016. The study is approved until 11/15/2017.

Review Category: Expedited Categories #6 & 7

Copies of all approved documents are available in the study's **Final** Documents (far right column under the documents tab) list in the eIRB.

Ongoing IRB submission requirements:

- Six to ten weeks before the expiration date, you are to submit a continuing review to request continuing approval.
- Any changes to the project must be submitted for IRB approval prior to implementation.

- Reportable New Information must be submitted per OHSU policy.
- You must submit a continuing review to close the study when your research is completed.

Guidelines for Study Conduct

In conducting this study, you are required to follow the guidelines in the document entitled, "Roles and Responsibilities in the Conduct of Research and Administration of Sponsored Projects," as well as all other applicable OHSU IRB Policies and Procedures.

Requirements under HIPAA

If your study involves the collection, use, or disclosure of Protected Health Information (PHI), you must comply with all applicable requirements under HIPAA. See the HIPAA and Research website and the Information Privacy and Security website for more information.

IRB Compliance

The OHSU IRB (FWA00000161; IRB00000471) complies with 45 CFR Part 46, 21 CFR Parts 50 and 56, and other federal and Oregon laws and regulations, as applicable, as well as ICH-GCP codes 3.1-3.4, which outline Responsibilities, Composition, Functions, and Operations, Procedures, and Records of the IRB.

Sincerely,

The OHSU IRB Office

Appendix 3- Telephone Recruitment and Screening Script

eIRB #16210

IRB Approved: 11/16/2016

Hello, my name is Wafaa BinAli. I'm calling from Oregon Health & Science University about a research study. Am I speaking to _____ (name of recruit)?

If "no," wait for recruit to pick up, arrange to leave a message, or ask for a time to call back.

If "yes":

I am calling you because you sent me an email saying that you would like to participate in this study. Is this a good time to talk? I expect this phone call will take about 10 minutes.

Arrange to call at another time, if appropriate.

I'm calling about a research study of CRRT in the ICU called "Perceived impact of ICU work environment on continuous renal replacement therapy (CRRT) practice, ICU nurses' performance, quality of care, and patient safety". The purpose of this research study is to learn more about how ICU nurses perceive the impact of ICU work environment on the CRRT care practice.

I'm calling to see if you are interested and if you might be eligible to participate. If you agree, I will ask you some questions to see if you can be in the study. If it looks like you might be eligible, I will discuss the study with you in more detail. I will email you a copy of the information sheet so you can review it and let me know later if you would like to participate.

Before we go on to the questions, let me tell you a little bit about your rights as a research subject.

The main risk of answering my questions today is loss of confidentiality. However, we will do our best to keep your information confidential by assigning you an ID number and use it throughout the research study. All hard copy documents will be kept in a locked cabinet and electronic documents will be kept in a password-protected folder on password-protected computer. If you are not eligible for this study, we will destroy the record of this phone call.

You don't have to answer these questions, and you can choose to stop at any time without penalty. If you have questions about the study, you can call me at (503)560-4344 or email me at binali@ohsu.edu. If you have questions about your rights as a research subject or research-related injuries, you can call the OHSU Research Integrity Office at 503-494-7887.

May I go ahead with the eligibility questions?

If no, thank the individual and end the call.

If yes:

IRB Approved: 11/16/2016

eIRB #16210

I'm going to give a list of things that would make you eligible for being in the study. Please do not indicate if these things apply to you until the end of the list. When I'm finished with the list, feel free to ask questions or tell me if you do have the following:

1) Registered nurses who work full-time in the ICU
2) Minimum of 1-year experience as ICU nurse to ensure enough exposure to the ICU environment, and completion of unit competencies
3) Completed formal training on CRRT and competency has been signed off by a preceptor
4) Managed CRRT a minimum of 2 times in the past 6 months

If all of those things are true for you, you can participate in the study. Does it look like you might still be eligible?

If yes: Document eligibility response and make appointment, if appropriate.

If no:

Thank you for your time.

Appendix 4- Qualitative Study Information Sheet

IRB Approved: 11/16/2016
Approval Expires: 11/15/2017

OREGON HEALTH & SCIENCE UNIVERSITY

Information Sheet

IRB# 16210

TITLE: Perceived impact of ICU work environment on continuous renal replacement therapy (CRRT) practice, ICU nurses' performance, quality of care, and patient safety.

PRINCIPAL INVESTIGATOR: Dr. Dena Hassouneh (503) 494-2714

CO-INVESTIGATORS: Wafaa BinAli (503) 560-4344

FUNDED BY: The school of Nursing

PURPOSE:
You have been invited to be in this research study because you are an ICU nurse with CRRT experience. The purpose of this study is to learn more about how ICU nurses perceive the impact of the ICU work environment on delivery of CRRT.

PROCEDURES:
Enrollment in this study involves participation in one or two qualitative interviews. Interviews will be conducted via telephone or in person at any location of your choice. You will be asked to share your experiences as an ICU nurse who manages CRRT.

The first interview will take up 60 minutes and the second interview, if applicable, will take up to 30 minutes.

Both interviews will use a semi-structured conversational format and will be audio-recorded and transcribed verbatim, by a professional agency, for analysis. After you complete the second interview, if applicable, your participation in the study is over.

You may choose to not participate or to stop participating at any time. A copy of this information sheet will be provided (either sent to your email or handed to you). If you have any questions, concerns, or complaints regarding this study now or in the future, or you think you may have been injured or harmed by the study, contact Wafaa BinAli at (503) 560-4344 or email binali@ohsu.edu.

RISKS:
Although we have made every effort to protect your identity, there is a minimal risk of loss of confidentiality. Additionally, sharing your story may upset you. If you become upset during an interview you may ask the investigator to turn of the tape recorder or to take a break. You can also withdraw from the study at any time for any reason.

BENEFITS:
You will not benefit from being in this study. However, by serving as a subject, you may help us learn how to benefit patients in the future.

CONFIDENTIALITY:
We will take steps to keep your personal information confidential, but we cannot guarantee total privacy.

You will be assigned an ID number and we will use it when analyzing data. Interviews will be recorded using a digital audio device. Interviews will be in an electronic (MP3) format, transferred to a secure encrypted drive for storage, and given to a contracted professional agent for transcription. All transcripts will be coded to protect confidentiality for each research participant. Upon confirmation of the transcript quality and accuracy, the original audio files will be deleted to prevent the retention of any potentially identifying "voiceprints." All paper documents will be kept in a locked drawer in a locked office for storage.
Electronic documents will be kept encrypted and stored in an encrypted OHSU computer for safety.

COSTS:
It will not cost you anything to participate in this study. You will receive $10 gift card after completing each interview.

PARTICIPATION:
This research is being overseen by an Institutional Review Board ("IRB"). You may talk to the IRB at (503) 494-7887 or irb@ohsu.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research subject.
- You want to get more information or provide input about this research.

You may also submit a report to the OHSU Integrity Hotline online at https://secure.ethicspoint.com/domain/media/en/gui/18915/index.html or by calling toll-free (877) 7338313 (anonymous and available 24 hours a day, 7 days a week).

You do not have to join this or any research study. If you do join, and later change your mind, you may quit at any time. If you refuse to join or withdraw early from the study, there will be no penalty or loss of any benefits to which you are otherwise entitled.

The participation of OHSU employees in OHSU research is completely voluntary and you are free to choose not to serve as a research subject in this protocol for any reason. If you do elect to participate in this study, you may withdraw from the study at any time without affecting your relationship with OHSU, the investigator, the investigator's department, or your grade in any course. If you would like to report a concern with regard to participation of OHSU employees in OHSU research, please call the OHSU Integrity Hotline at 1-877-733-8313 (toll free and anonymous). We will give you a copy of this information sheet.

Appendix 5- Qualitative Study Demographic Questions

ID#:_ _ _ _ _ _

Demographic form

Gender: **(__)** Male (__) Female

Age: (__) 24-34 (__) 35-44 (__) > 45

Race: (__) White (__) African American (__) Hispanic
(__) Asian (__) American Indian/Alaska Native
(__) Native Hawaiian/Pacific Islander (__) Other_____

ICU type: (__) 12K (__) 8C (__) 7A

RN years of experience: (__) 1-5 y (__) 6-10 y (__) >10 y

ICU years of experience: (__) 1-2 y (__) 3-5 y (__) 6-10 (__) >10 y

CRRT years of experience: (__) 1-2 y (__) 3-5 y (__) 6-10 (__) >10 y

Highest educational degree: (__) Associate (__) BS/BSN/BA (__) MS/MSN
(__) Other_____

Shifts mostly work: (__) Day shift (__) Night shift

Appendix 6- Interview Guide

1. Can you tell me about your experiences when managing CRRT?
   Probes:
   a. What was your experience like when you were assigned to a patient on CRRT for the first time?
   b. What influenced your experience either positively or negatively?
   c. What are the challenges you encountered when managing CRRT?
   d. Describe to me the interaction you had with other providers when managing CRRT (physicians, fellow nurses)?
   e. Who else do you need to interact with when you manage CRRT?
   f. What was your experience like when operating the CRRT machine?
   g. How have your experiences changed over time?

2. Tell me about the training you received on CRRT?
   Probes:
   a. How do you feel about your competency level when you manage CRRT?
   b. What would you change to help you feel more competent?

3. How management helps in supporting you when managing CRRT? Probe:
   a. What the management does to ensure proper staffing for CRRT?
   b. Is the CRRT policy and procedure manual accessible to you?
   c. What resources are made available to you when managing CRRT?

4. What factors in the ICU physical environment facilitate or hinder CRRT practice?
   Probes:
   a. Does the supply room location affect work load?
   b. How do you feel about the physical layout of the patient room and the fit of the CRRT machine in the room?

5. What does CRRT quality mean to you?
   Probes:
   a. What do you do to ensure quality while managing CRRT?
   b. How do you assess quality of CRRT?
   c. How can the quality of CRRT be improved?
   d. How the ICU environment might impact CRRT quality?

6. What patient safety issues have you encountered when managing CRRT? Probes:
   a. What factors in the ICU work environment contributed to these issues?
   b. How do you think these issues can be managed to ensure safety of CRRT?

7. Can you explain how the ICU work environment might impact your performance when delivering CRRT??
   Probe:
   a. What factors in the ICU work environment impact your performance when managing CRRT?
   b. How do you think performance be measured when managing CRRT?

8. What changes do you think are needed to support CRRT management?
   Probes:
   a. Can you give me some examples?

9. Is there anything else you want to add?

Appendix 7- Pilot Study Information Sheet

IRB Approved: 10/23/2018
Approval Expires: 10/22/2019

OREGON HEALTH & SCIENCE UNIVERSITY

Information Sheet

IRB# 16210

TITLE: Perceived impact of ICU work environment on continuous renal replacement therapy (CRRT) practice, ICU nurses' performance, quality of care, and patient safety.

PRINCIPAL INVESTIGATOR: Dr. Dena Hassouneh (503) 494-2714

CO-INVESTIGATORS: Wafaa BinAli (503) 560-4344

FUNDED BY: 1- OHSU-School of Nursing
2- Hartford Center of Gerontological Nursing Excellence at OHSU
3- Sigma Theta Tau International, Beta Psi Chapter

PURPOSE:
You have been invited to be in this research study because you are an ICU nurse with CRRT experience. The purpose of this study is to learn more about how ICU nurses perceive the impact of the ICU work environment on delivery of CRRT.

PROCEDURES:
Enrollment in this study involves completion of a survey. The survey consists of an instrument that measures the perceived impact of the ICU work environment on CRRT practice, ICU nurses' performance, quality of care, and patient safety. Also, you will answer some demographic questions to help us to understand your experience with CRRT. Completing the survey will take 10-15 minutes.

After you complete the survey and return it to the investigator, your participation in the study is over.

You may choose to not participate or to stop participating at any time. A copy of this information sheet will be provided (will be included in the survey package). If you have any questions, concerns, or complaints regarding this study now or in the future, or you think you may have been injured or harmed by the study, contact Wafaa BinAli at (503) 560-4344 or email binali@ohsu.edu.

RISKS:
Although we have made every effort to protect your identity, there is a minimal risk of loss of confidentiality. Additionally, sharing your story may upset you. If you become upset during an

interview you may ask the investigator to turn of the tape recorder or to take a break. You can also withdraw from the study at any time for any reason.

BENEFITS:
You will not benefit from being in this study. However, by serving as a subject, you may help us learn how to benefit patients in the future.

CONFIDENTIALITY:
We will take steps to keep your personal information confidential, but we cannot guarantee total privacy. You will be assigned an ID number and we will use it when analyzing data. All paper documents will be

kept in a locked drawer in a locked office for storage. Electronic documents will be kept encrypted and stored in an encrypted OHSU computer for safety.

COSTS:
It will not cost you anything to participate in this study. You will receive $10 gift card for completing the survey.

PARTICIPATION:
This research is being overseen by an Institutional Review Board ("IRB"). You may talk to the IRB at (503) 494-7887 or irb@ohsu.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research subject.
- You want to get more information or provide input about this research.

You may also submit a report to the OHSU Integrity Hotline online at https://secure.ethicspoint.com/domain/media/en/gui/18915/index.html or by calling toll-free (877) 7338313 (anonymous and available 24 hours a day, 7 days a week).

You do not have to join this or any research study. If you do join, and later change your mind, you may quit at any time. If you refuse to join or withdraw early from the study, there will be no penalty or loss of any benefits to which you are otherwise entitled.

The participation of OHSU employees in OHSU research is completely voluntary and you are free to choose not to serve as a research subject in this protocol for any reason. If you do elect to participate in this study, you may withdraw from the study at any time without affecting your relationship with OHSU, the investigator, the investigator's department, or your grade in any course. If you would like to report a concern with regard to participation of OHSU employees in OHSU research, please call the OHSU Integrity Hotline at 1-877-733-8313 (toll free and anonymous).

Appendix 8- AACN Study Invitation Postcard

IRB Approved: 10/23/2018

Dear ICU nurse,

As a CCRN member, we are inviting you to participate in a research study looking at the perceived impact of the ICU work environment on CRRT practice.

With your help, we can identify factors in the ICU work environment that impact CRRT practice, ICU nurses' performance, quality of CRRT care, and patient safety. All you need to do is complete an online survey. Please go to http://binaliws.wixsite.com/crrtsurvey and follow the directions!

All participation is voluntary, and responses are confidential.

If you have any questions, please contact Wafaa BinAli at 503-560-4344 or email binali@ohsu.edu.

We hope that you will consider taking part in this study. Thank you!!

Sincerely,

Wafaa BinAli
PhD Candidate

Postal stamp

To:

IRB Approved: 10/23/2018

If you are an ICU nurse with CRRT experience, then you are invited to participate in this research study!!

And you might win a prize….

Appendix 9- National Study Information Sheet

IRB Approved: 10/23/2018
Approval Expires: 10/22/2019

OREGON HEALTH & SCIENCE UNIVERSITY

Information Sheet

IRB# 16210

TITLE: Perceived impact of ICU work environment on continuous renal replacement therapy (CRRT) practice, ICU nurses' performance, quality of care, and patient safety.

PRINCIPAL INVESTIGATOR: Dr. Dena Hassouneh (503) 494-2714

CO-INVESTIGATORS: Wafaa BinAli (503) 560-4344

FUNDED BY: 1- OHSU-School of Nursing
2- Hartford Center of Gerontological Nursing Excellence at OHSU
3- Sigma Theta Tau International, Beta Psi Chapter

PURPOSE:
You have been invited to be in this research study because you are an ICU nurse with CRRT experience. The purpose of this study is to learn more about how ICU nurses perceive the impact of the ICU work environment on delivery of CRRT.

PROCEDURES:
Enrollment in this study involves completion of a survey. The survey consists of an instrument that measures the perceived impact of the ICU work environment on CRRT practice, ICU nurses' performance, quality of care, and patient safety. Also, you will answer some demographic questions to help us to understand your experience with CRRT. Completing the survey will take 7-10 minutes.

You will complete the survey online via REDCap. Make sure you answer all questions and hit "complete" after you finish. You can save your answers and come back later to complete the survey. You may choose to not participate or to stop participating at any time. If you have any questions, concerns, or complaints regarding this study now or in the future, or you think you may have been injured or harmed by the study, contact Wafaa BinAli at (503) 560-4344 or email binali@ohsu.edu.

RISKS:
Although we have made every effort to protect your identity, there is a minimal risk of loss of confidentiality. Additionally, sharing your story may upset you. If you become upset during an interview you may ask the investigator to turn of the tape recorder or to take a break. You can also withdraw from the study at any time for any reason.

BENEFITS:
You will not benefit from being in this study. However, by serving as a subject, you may help us learn how to benefit patients in the future.

CONFIDENTIALITY:
We will take steps to keep your personal information confidential, but we cannot guarantee total privacy. You will be assigned an ID number and we will use it when analyzing data. Electronic documents will be kept encrypted and stored in an encrypted OHSU computer for safety.

COSTS:
It will not cost you anything to participate in this study. Once you have completed the survey, your ID number will be entered in a raffle to win one of the following AACN publication books: 1) AACN Core Curriculum for High Acuity, Progressive, and Critical Care Nursing, 7th Ed. (2 copies, one for each winner), 2) Ace the CCRN! You Can Do It! Study Guide (2 copies, one for each winner), and 3) Lange Critical Care (1 copy). All these books were purchased from AACN and the primary investigator will mail them to winners.

PARTICIPATION:
This research is being overseen by an Institutional Review Board ("IRB"). You may talk to the IRB at (503) 494-7887 or irb@ohsu.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research subject.
- You want to get more information or provide input about this research.

You may also submit a report to the OHSU Integrity Hotline online at https://secure.ethicspoint.com/domain/media/en/gui/18915/index.html or by calling toll-free (877) 7338313 (anonymous and available 24 hours a day, 7 days a week).

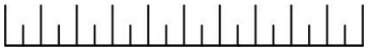
You do not have to join this or any research study. If you do join, and later change your mind, you may quit at any time. If you refuse to join or withdraw early from the study, there will be no penalty or loss of any benefits to which you are otherwise entitled.

The participation of OHSU employees in OHSU research is completely voluntary and you are free to choose not to serve as a research subject in this protocol for any reason. If you do elect to participate in this study, you may withdraw from the study at any time without affecting your relationship with OHSU, the investigator, the investigator's department, or your grade in any course. If you would like to report a concern with regard to participation of OHSU employees in OHSU research, please call the OHSU Integrity Hotline at 1-877-733-8313 (toll free and anonymous).

Please print this page and keep a copy as a record for your participation in this study.

Appendix 10- NASA Task Load Index (NASA-TLX) Scale

The following questions deal with the workload that you experience in your job. Please put an 'X' on each of the following six scales at the point that matches your overall experience of workload when managing CRRT.

	Low	High
1. **Mental demand.** How much mental activity is required to perform your job (thinking, deciding, calculating, remembering, looking, searching, etc…)?		
2. **Physical demand.** How much physical activity is required to perform your job (e.g., pushing, pulling, turning, controlling, activating, etc.)?		
3. **Temporal demand.** How much time pressure do you feel due to the rate or pace at which the tasks or task elements occurred?		
4. **Effort.** How hard do you have to work (mentally and physically) to accomplish your level of performance?		
5. **Performance.** How satisfied are you with your performance at your job?		
6. **Frustration level.** How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent do you feel about your job?		

Appendix 11- ICU Work Environment and CRRT Questionnaire

Questionnaire

Wafaa BinAli, MSN
Dena Hassouneh, Ph.D., RN, ANP, PMHNP, FAAN

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Letter to ICU Nurses

Dear ICU Nurse:

Our research team is working on a study of the ICU work environment and CRRT. This survey is part of the effort to evaluate the impact of the ICU work environment on CRRT practice, ICU nurses' performance, and quality and safety of CRRT care.

Participation in this study is voluntary. If you do agree to be in the study, you are asked to fill out the following questionnaire, which will tell us about the factors in your work environment. The questionnaire will only take about 15 minutes to complete. When completing the questionnaire, you can leave any questions blank that you do not want to answer. No one at your work place will ever see your answers. Your responses are strictly confidential and will be closely guarded.

We need your help to make this research study successful. Your participation in this study will enable us to gain a clearer understanding of the impact of ICU work environment on CRRT. We hope you agree to participate. Thank you for your consideration.

Sincerely,

Wafaa BinAli, MSN,RN

Please answer the following questions considering the ICU unit where you are currently working, focusing on your experience with CRRT.

Items		***Strongly disagree*** **1**	***Disagree*** **2**	***Neither agree nor disagree*** **3**	***Agree*** **4**	***Strongly Agree*** **5**
1-	The CRRT machine is easy to operate	1	2	3	4	5
2-	I can move the CRRT machine easily in the patient's room	1	2	3	4	5
3-	The CRRT machine has clear instructions for set-up	1	2	3	4	5
4-	The CRRT machine has clear instructions for troubleshooting	1	2	3	4	5
5-	I can easily read the data from the CRRT machine display screen	1	2	3	4	5
6-	The display screen on the CRRT machine is well lit and clear	1	2	3	4	5
7-	Setting up the CRRT machine takes a great deal of time	1	2	3	4	5
8-	CRRT filters frequently clot	1	2	3	4	5
9-	I often encounter technical problems when using the CRRT machine	1	2	3	4	5
10-	Patients' rooms are often too small to fit the CRRT machine along with other equipment and extra CRRT supplies	1	2	3	4	5
11-	Multiple alarms coming from different equipment can mask the CRRT machine alarm	1	2	3	4	5
12-	It is hard for patients to sleep when the CRRT machine is running	1	2	3	4	5
13-	Keeping CRRT supplies in the patient's room makes my work life easier	1	2	3	4	5
14-	The layout of my unit allows me to quickly get what I need for CRRT	1	2	3	4	5
15-	Patients' comorbid conditions and diagnoses influence the duration of CRRT circuit life	1	2	3	4	5
16-	CRRT restricts patient's movement	1	2	3	4	5
17-	Patients on CRRT are often very sick to the point of being unmanageable	1	2	3	4	5
18-	Despite having been through the informed consent process, families and patients often request further information about the CRRT process from me	1	2	3	4	5
19-	I am assigned to only one patient on CRRT per shift	1	2	3	4	5
20-	There is always another CRRT-trained nurse available to support me during my shift	1	2	3	4	5
21-	Other nurses help me when managing CRRT	1	2	3	4	5
22-	The charge nurse is CRRT-trained and helps me when needed	1	2	3	4	5
23-	I can use the CRRT manufacturer hotline phone to trouble shoot a problem when I need to	1	2	3	4	5
24-	I can easily get supplies in a timely manner during my shift	1	2	3	4	5

Items		***Strongly disagree* 1**	***Disagree* 2**	***Neither agree nor disagree* 3**	***Agree* 4**	***Strongly Agree* 5**
25-	It is easy to coordinate with other departments to ensure there is an adequate supply of fluid bags and medications	1	2	3	4	5
26-	I receive clear information about CRRT during the nurse-to-nurse shift hand-off	1	2	3	4	5
27-	It is clear which provider I need to contact regarding CRRT notifications and questions	1	2	3	4	5
28-	I can reach the on-call physician to report changes in my patient's condition at any time	1	2	3	4	5
29-	My workload increases when CRRT is added to the care plan	1	2	3	4	5
30-	There is always a CRRT-trained nurse available to relieve me for breaks	1	2	3	4	5
31-	If my patient's condition is unstable and CRRT is added, I always get another nurse to help me during the shift	1	2	3	4	5
32-	Emptying the CRRT effluent bag is cumbersome	1	2	3	4	5
33-	The CRRT training I received prepared me well to independently manage this therapy	1	2	3	4	5
34-	Every year I have a hard time maintaining my CRRT competency due to low frequency of CRRT patient assignments	1	2	3	4	5
35-	Using a CRRT machine for a hands-on practice during the CRRT training course was helpful	1	2	3	4	5
36-	The more I practice CRRT, the easier it gets	1	2	3	4	5
37-	Maintaining staff competence with CRRT is a big concern on our unit	1	2	3	4	5
38-	I am satisfied with my performance managing CRRT	1	2	3	4	5
39-	I plan ahead when managing CRRT to avoid running out of supplies (fluids, filter, medications, etc.)	1	2	3	4	5
40-	I am always able to achieve CRRT treatment goals during my shift	1	2	3	4	5
41-	CRRT is ordered for patients with a poor prognosis some of the time	1	2	3	4	5
42-	Most of the time CRRT is started too late in the patient's course of treatment	1	2	3	4	5
43-	Use of commercially available CRRT fluid bags reduces waste	1	2	3	4	5
44-	It is easy to run CRRT with minimal down time	1	2	3	4	5
45-	I am satisfied with the quality of the CRRT care I provide to my patients	1	2	3	4	5
46-	High patient care load decreases my ability to focus on CRRT	1	2	3	4	5
47-	I manage to return blood to the patient before stopping CRRT most of the time	1	2	3	4	5
48-	Using a barcode scanner reduces CRRT errors related to medication and fluid administration	1	2	3	4	5
49-	I always have another CRRT-trained nurse to check CRRT orders and settings with me prior to initiation	1	2	3	4	5
50-	We always have two nurses double check medication orders related to CRRT prior to administration	1	2	3	4	5
51-	I can recognize signs of citrate toxicity and take appropriate actions	1	2	3	4	5
52-	CRRT fluid calculation errors occur frequently	1	2	3	4	5

53-	CRRT sometimes results in adverse events (any undesirable experience associated with the use of a medical product in a patient, for example, hypovolemic shock, seizures, significant bleeding, etc.)	1	2	3	4	5
54-	I am satisfied with the safety of the CRRT care I provide to my patients	1	2	3	4	5

Demographics

The following set of questions is about you and where you work

1- Age: _____

2- Gender: (__) Male (__) Female

3- Race/ethnicity :

(__) White
(__) Hispanic
(__) Asian
(__) Native Hawaiian/Pacific Islander
(__) African American
(__) Middle Eastern and North African
(__) American Indian/Alaska Native
(__) Multiple race

4- ICU type:

(__) Medical Intensive Care Unit
(__) Neurological Intensive Care Unit
(__) Trauma Intensive Care Unit
(__) Other :_____
(__) Surgical Intensive Care Unit
(__) Cardiac Intensive Care Unit
(__) General Intensive Care Unit (mixed)

5- How many beds are there in your unit? _____

6- Is your hospital a teaching hospital? Yes____ No ____

7- Your hospital is located in: (__) Urban area (__) Rural area

8- The State you are working at:_____ (write two–letter state abbreviation e.g., CA)

9- RN years of experience: _____

10- ICU years of experience: _____

11- CRRT years of experience: _____

12- Which CRRT machine do you currently use?

(__) PrismaFlex (Baxter Medical)
(__) Diapact System (B-Braun)
(__)NxStage System One (NxStage Medical)
(__) Other :_____

13- How often have you managed CRRT in the past year? _____ times

14- How long have you worked in your current ICU? _____ years _____ months

15- Highest educational degree:
(__) Associate (__) BS/BSN/BA
(__) MS/MSN (__) DNP/PhD

16- What is your current job position?
(__) Staff RN (__) Float RN
(__) Travel/Agency RN (__) Other (please specify): _____

17- Which shift do you work usually?
(__) Day (first shift) (__) Evening (second shift) (__) Night (third shift)

18- When during the week do you typically work? (__) Weekdays (__) Weekends (__) Both

19- How long is your shift? (__) 8 hours (__) 12 hours (__) Other: _____

20- Does your unit monitor CRRT specific quality indicators? Yes____ No ____
If yes, please list here:_____

21- Who orders CRRT in your unit?
(__) Nephrologist (__) ICU team/ intensivist (__) Both teams collaboratively

22- Who evaluates your CRRT performance? (Check all that apply)
(__) My peers (__) CRRT educator (__) Nurse manager

CRRT training:

23- How long was your class time:_____ hours per day

24- Was the class held for more than one day? Yes____ No ____
If yes, how many days?_____

25- Was shadowing a CRRT-trained nurse part of completing your CRRT training? Yes__ No__
If yes, how many shifts did you shadow a preceptor? _____

26- Is there a number of patients on CRRT that you have to care for annually to maintain your CRRT competency level? Yes__ No__
If Yes, how many patients per year?_____

You have completed the questionnaire. Thank you for your time!

Appendix 12- The NICE Scale

Please answer the following questions considering the ICU unit where you are currently working, focusing on your experience with CRRT.

Items	***Strongly disagree* 1**	***Disagree* 2**	***Neither agree nor disagree* 3**	***Agree* 4**	***Strongly Agree* 5**
1- The CRRT machine is easy to operate	**1**	**2**	**3**	**4**	**5**
2- The CRRT machine has clear instructions for troubleshooting	**1**	**2**	**3**	**4**	**5**
3- I can easily read the data from the CRRT machine display screen	**1**	**2**	**3**	**4**	**5**
4- The display screen on the CRRT machine is well lit and clear	**1**	**2**	**3**	**4**	**5**
5- Setting up the CRRT machine takes a great deal of time	**1**	**2**	**3**	**4**	**5**
6- CRRT filters frequently clot	**1**	**2**	**3**	**4**	**5**
7- I often encounter technical problems when using the CRRT machine	**1**	**2**	**3**	**4**	**5**
8- Patients' rooms are often too small to fit the CRRT machine along with other equipment and extra CRRT supplies	**1**	**2**	**3**	**4**	**5**
9- Other nurses help me when managing CRRT	**1**	**2**	**3**	**4**	**5**
10- The charge nurse is CRRT-trained and helps me when needed	**1**	**2**	**3**	**4**	**5**
11- I can use the CRRT manufacturer hotline phone to trouble shoot a problem when I need to	**1**	**2**	**3**	**4**	**5**
12- I receive clear information about CRRT during the nurse-to-nurse shift hand-off	**1**	**2**	**3**	**4**	**5**
13- I can reach the on-call physician to report changes in my patient's condition at any time	**1**	**2**	**3**	**4**	**5**
14- My workload increases when CRRT is added to the care plan	**1**	**2**	**3**	**4**	**5**
15- If my patient's condition is unstable and CRRT is added, I always get another nurse to help me during the shift	**1**	**2**	**3**	**4**	**5**
16- The more I practice CRRT, the easier it gets	**1**	**2**	**3**	**4**	**5**
17- Maintaining staff competence with CRRT is a big concern on our unit	**1**	**2**	**3**	**4**	**5**
18- I am satisfied with the quality of the CRRT care I provide to my patients	**1**	**2**	**3**	**4**	**5**
19- We always have two nurses double check medication orders related to CRRT prior to administration	**1**	**2**	**3**	**4**	**5**
20- I can recognize signs of citrate toxicity and take appropriate actions	**1**	**2**	**3**	**4**	**5**
Satisfaction Scale	***Strongly disagree* 1**	***Disagree* 2**	***Neither agree nor disagree* 3**	***Agree* 4**	***Strongly Agree* 5**
1- I am satisfied with my performance managing CRRT	**1**	**2**	**3**	**4**	**5**
2- I am satisfied with the quality of the CRRT care I provide to my patients	**1**	**2**	**3**	**4**	**5**
3- I am satisfied with the safety of the CRRT care I provide to my patients	**1**	**2**	**3**	**4**	**5**