PATIENTS’ VITAL SIGNS AND THE LENGTH OF TIME BETWEEN THE MONITORING OF VITAL SIGNS DURING TIMES OF EMERGENCY DEPARTMENT CROWDING

By
KIMBERLY D. JOHNSON

Submitted in partial fulfillment of the requirements
For the degree of Doctor of Philosophy

Dissertation Advisor: Dr Chris Winkelman

Frances Payne Bolton School of Nursing
CASE WESTERN RESERVE UNIVERSITY

May, 2011
We hereby approve the thesis/dissertation of

K. D. Johnson

candidate for the PhD degree *

(signed) Chris Winkelman

(chair of the committee)

Mary A. Dolansky

Vicken Y. Totten MD

Christopher J. Burant

(date) December 17, 2010

*We also certify that written approval has been obtained for any proprietary material contained therein.
DEDICATION

I dedicate my dissertation to my wonderful family without whom I could not have completed this project. To Erik, my supportive and understanding husband, thank you for not letting me quit and for your endless encouragement and patience. Richard Samuel, you’re the best project I ever completed. When I started this program I never dreamt that I would finish it with a degree and a child. God is good. My parents, Donald and Shirley Blasko, I thank you for inspiring me to become a nurse as well as emphasizing the importance of education, hard work and setting priorities. To my ‘spare’ parents, Richard and Susan Johnson, thanks for your love, support and free babysitting service.
# Table of Contents

List of Tables ........................................................................................................ viii
List of Figures ........................................................................................................ x
Acknowledgements ................................................................................................ xi
Abstract .................................................................................................................. xii

## Chapter One

Introduction ............................................................................................................. 1
Purpose of the study ............................................................................................... 3
Background and Significance ................................................................................. 3
Effect of ED Crowding on Quality Care Indicators ............................................ 5
Cost of ED Crowding ............................................................................................ 6
The Role of the Emergency Nurse ...................................................................... 8
Problem statement ............................................................................................... 8
Theoretical Framework ......................................................................................... 9
Vital Signs ............................................................................................................ 22
Research questions ............................................................................................. 28
Significance of study ........................................................................................... 28
Assumptions of the study .................................................................................. 31
Definition of Terms ............................................................................................ 31

## Chapter Two

Literature Review ................................................................................................. 36
ED Crowding ....................................................................................................... 36
ED Crowding and Adverse Outcomes ............................................................... 41
Chapter Three

Methods

Setting

Sample

Data Collection /Study Procedures

Chart Extraction

Instrumentation

ED Crowding

Demographic Variables

Arrival Information

Patient Health Status

Triage Category

Vital Signs

Nurses’ Response to Abnormal Vital Signs

Additional Contextual Factors

Human Subjects

Data Protection

Data Management

Data Analysis

Chapter 4
Appendix 1  ESI Triage Algorithm 151

Appendix 2 Results of testing the primary and secondary assumption of regression for Research Question 1 152

Appendix 3 Results of primary and secondary assumptions of regression for Research Question 2 153

Appendix 4 Transformation for Research Question 2: Linearity of Age variable 158

Appendix 5 Results of Transformation to Improve Linearity of OTC Variable for Research Question 2 159

Appendix 6 Results of Transformation to Improve Linearity of Med Route Variable for Research Question 2 160

Appendix 7 PI designed data collection tool 161

References 164
List of Tables

1. Variables representing Concepts in Hypothesized Model__________20
2. Literature review tables
   2-1 Studies that examined the association between
      ED crowding and adverse outcomes____________________62
   2-2 Studies that examined Quality of care in ED______________68
   2-3 Studies that look at the assessment of vital signs/physiological
      changes as prediction of adverse outcomes_______________70
3. MEWS calculation________________________________________87
4. List of data points collected_______________________________90
5. Summary of Vital Signs during all 3 time points collected______102
6. Summary of Factors Theorized to Affect the Length of Time
      Between Vital Signs____________________________________103
7. Summary of Correlation Analysis for EDWIN score on Minutes
      Between Vital Signs (N=192)____________________________104
8. Descriptive Statistics for Variables Included in Research
      Question 2____________________________________________106
9. Analysis of Collinearity and Correlations to the Length of
      Time (min) between Vital Sign Recordings_________________110
10. Explained variance for the Length of Time between Vital
    Sign Recordings________________________________________110
11. Results of Goodness of Fit Indices with Removal of
    Nonsignificant paths____________________________________112
12. Summary of Significant Regression weights for Endogenous Variables ........................................ 116

13. Summary of Covariances ........................................................................................................... 116

14. Descriptive stats for Research Question 3 variables ................................................................. 119

15. Correlations between the Time from Abnormal vital sign Acknowledgement to Reaction time ................................................................. 119

16. Descriptive statistics for Research Question 4 ......................................................................... 121

17. Results of Regressions of EDWIN score on Vital signs (MEWS) ........................................... 121

18. The Effect of Crowding on changes in Individual Vital Signs .................................................. 121
List of Figures

2. Figure 2. Modification to Asplin model .............................. 15
3. Donabedian Structure-Process-Outcome ...................... 16
4. Modified Model of ED Crowding .................................... 19
5. Tested portion on of modified model of ED crowding .......... 19
6. Hypothesized relationships among study variables .......... 21
7. Substruction of Theoretical Model ................................. 22
8. Original Hypothetical Model ....................................... 111
9. Final Model with Standardized Regression Weights .......... 114
10. The modified model of ED crowding .............................. 138
ACKNOWLEDGEMENTS

I would like to thank all of the people that made this dissertation possible. I am incredibly grateful for the many colleagues and friends that have provided support, clarification, inspiration and guidance to me during this endeavor. First, I thank my advisor, Chris Winkelman for all of your guidance, encouragement and patience. I have learned more from you than you will ever know. Thank you for entertaining all of my many, many research ideas and helping me narrow those ideas into something manageable. I am inspired by your excitement and dedication to research. I would also like to thank Chris Burant for making statistics fun and understandable. Next, I thank Mary Dolansky. Your passion for quality improvement is infectious. Thank you for providing me with direction in the development of my conceptual model. I would like to thank Dr. Vicken Totten for providing a unique perspective that added depth and meaning to this project. I would like to say a special thank you to Amy Bieda and Jean Chiang for providing much laughter and a reprieve from my long commute. I will forever be grateful for your room and board and friendship. Finally, I acknowledge the staff in the Medical Records Department at UHCMC who was incredibly helpful and efficient.
Patients’ Vital Signs and the Length of Time between the Monitoring of Vital Signs During Times of Emergency Department Crowding

Abstract

By

KIMBERLY D. JOHNSON

The purpose of this study was to examine patients’ vital signs and what factors influence the length of time between vital sign recordings during various levels of ED crowding. Secondary purposes were to explore the nurse’s response when vital signs were abnormal and to investigate the effect of ED crowding on the occurrence of abnormal vital signs. Vital signs are an integral component of the nursing assessment and often used as a decision-making tool. There is limited information about discernment of clues (i.e. vital sign abnormalities) that precede catastrophic outcomes. It is not known if crowding affects vigilance and reporting/communicating in the presence of clues. Current research does not provide information of the effect that ED crowding on the quality of care provided to ED patients by nurses. A conceptual model was developed for this study by merging Asplin’s Model of ED Crowding and Donabedian’s Structure-Process-Outcome Model. A descriptive, retrospective chart review was performed of 202 randomly selected adult ED patients’ charts using a strategic sampling plan to capture a variety of ED occupancy scenarios at an urban, teaching hospital. Data was analyzed using multiple regression, correlation and Structural Equation Modeling. The results of this study demonstrated that: (a) as crowding increased,
the time between vital signs increased significantly but the clinical importance of this finding needs further investigation, (b) several factors contributed to the length of time between vital sign recordings: length of stay, triage category and patients arriving by private car had the greatest predictive value, (c) reactions to abnormal vital signs were not commonly documented by nursing in the handwritten records used for this project (d) ED crowding did not have an effect on the composite vital signs of patients. Results from this study may contribute to establishing a standard of care related to frequency of vital signs monitoring. Future study should focus on determining if frequency of vital signs surveillance contributes to high quality care. Findings also provide direction for future research linking quality of care to missing vital signs or inadequate monitoring and ED team response to abnormal vital signs.
Chapter One

Introduction

Patient crowding in the Emergency Department (ED), first defined in 1989 (Dickinson), has become a daily obstacle in EDs worldwide and is a critical problem affecting over 114 million patients annually in the United States alone (IOM, 2006; Richardson, 2006). ED crowding gained public attention due to media reports on adverse events when patients were not being examined or attended to by ED staff in what was considered an acceptable amount of time. Incidents of patients’ conditions deteriorating during long waits in crowded ED waiting rooms, as well as ill patients leaving the ED without being seen by a physician, leading to death and disability of these patients, have made frequent appearances on many of the national news networks (Bourgeois, Shannon, Stack, 2008; Vieth & Rhodes, 2006). Numerous studies have validated the concerns of the American public regarding the ability of EDs to provide quality care during periods of increased patient volume (Horwitz, Meredith, Schuur, Shah, Kulkarni, & Jenq, 2008; Pines & Hollander, 2008; Trzeciak & Rivers, 2003). For example, correlations have been identified between ED crowding and the increased occurrence of pneumonia, delayed treatment and excess mortality (Dunn, 2003; Fee, Weber, Maak, & Bacchetti, 2007; Fernandes, 2003; Richardson, 2006). Further, during periods of crowding, emergency nurses, physicians and patients report perceived decreases in the quality of care provided to patients (Pines, Garson, Baxt, Rhodes, Shofer & Hollander, 2007).
Little evaluation has been performed that examines how nurses respond during times of ED crowding. No matter how many patients are present in the ED, the emergency nurse is still required to perform assessments, assess vital signs, and provide care/medication as ordered by physicians and required by standards of practice. Much research has been conducted that examines the delays of (a) antibiotics to pneumonia patients (Fee, Weber, Maak, & Bacchettik 2007; Pines, et al., 2007), (b) thrombolytics to stroke and acute myocardial infarction (MI) patients (Ornato, 1991; Pines, Hollander, Localio, Metlay, 2006), (c) electrocardiogram and aspirin to MI patients (Diercks, Roe, Chen, Peacock, Kirk, Pollack, et al., 2007; Schull, Vermeulen, Slaughter, Morrison, & Daly, 2004), and (d) analgesics to patients with hip fractures (Hwang, Richardson, Sonuyi & Morrison, 2006; Mitchell, Kelly & Kerr, 2009). However, most of the ED patients are not included in any of these specific populations. No analysis has been performed on patients with abdominal pain of unknown etiology, migraine suffers, non-cardiac chest pain patients, or many other categories of patients that fall into common presentations or lower acuity categories. There are limited data about outcomes related to the quality of nursing care in the ED.

Research needs to be conducted to examine the relationship of ED crowding to the nurse’s role as well as important patient outcome measures. In order to address the issue of ED crowding completely, researchers must examine the consequences, not only the causes, of crowding. By examining relationships between ED crowding and nurse-sensitive patient outcomes, researchers can provide an evidence base from which improvements can be
made within the nursing practice. By examining factors that affect the frequency with which the emergency nurse monitors, interprets and reacts to abnormal vital signs, valuable information may be gained regarding the effect of ED crowding on this important role of the emergency nurse. This study was designed to guide future nursing research in determining interventions to help alleviate or prevent adverse outcomes that arise from abnormal vital signs when the ED was crowded.

Purpose of the study
The primary purpose of this study was to examine patients’ vital signs, and what factors influence the length of time between vital sign recordings during various levels of ED crowding. Secondary purposes included exploring the nurse's response when vital signs were abnormal and the effect of ED crowding on occurrence of abnormal vital signs.

Background and Significance
The Institute of Medicine (IOM) released a series of reports stating that emergency medical services in the U.S. are overwhelmed and underfunded (IOM, 2006). In response to the IOM reports, the Joint Commission on Accreditation of Healthcare Organizations (JC) has deemed that every hospital must have a plan to address the growing problem of crowding in the ED (Fee et al, 2007). However, few hospitals have developed an effective strategy to combat the daily occurrence of ED crowding.

Research has demonstrated that many factors have consistently contributed to ED crowding. Some of these factors are increased patient volume,
nursing staff shortages, decreased inpatient beds, increased acuity of patients entering the ED, and increased number of patients boarded in the ED (Magid, et al, 2004; Weiss, Ernst, & Nick, 2006).

The complex task of fixing the problem of crowding has been made more difficult by the lack of a consistent definition and terminology for ED crowding. Researchers have been divided on whether to label the problem as ED crowding or ED overcrowding and whether the two terms are degrees of the same problem. In 2003, Asplin et al. called for a paradigm shift that modified the accepted terminology of ‘ED overcrowding’ to a broader concept of ‘ED crowding’ in order to emphasize that overcrowding is simply one condition within the crowding scale. Richardson (2006) defined ED crowding as patient occupancy at, or greater than, the 75th percentile for a given time period. This definition has been used by dividing the day into six 4-hour intervals. For each time interval, the percent of total capacity for the ED was calculated. If the ED was over 75% occupied, it was considered crowded for the corresponding time interval. Although Richardson’s definition is simple to calculate, many researchers believe that it does not capture the multiple facets of ED crowding (ACEP, 2002; Asplin, et al, 2003). Other researchers have based their conceptual definition on the Crowding Resources Task Force of 2002 which states that crowding is a “situation in which the identified need for emergency services outstrips available resources in the ED” (Asplin, et al, 2003). According to the Task Force, this situation occurs when the number of ED patients outnumbers the staffed ED treatment beds and wait times exceed a reasonable period (ACEP, 2002). Pines
(2007) amended this definition to be quantifiable by defining ED crowding as any time when “inadequate resources to meet patient care demands lead to a reduction in the quality of care”.

**Effect of ED Crowding on Quality Care Indicators**

ED crowding has been associated with delays in cardiac intervention, analgesia and antibiotic administration (Christopher, et al, 2007; Hwang, Graff, Radford, & Krumholz, 2004; Hwang, Harris, Morrison, & Richardson, 2006; Jesse & Judd, 2008; Pines, Goyal, Band, & Gaieski, 2007). Although the majority of the studies concluded that ED crowding affects delays in antibiotic administration (Christopher, et al, 2007; Fee, et al, 2007; Hwang, et al, 2004), one study concluded that there was no association between ED crowding and delays in antibiotic administration (Pines, et al, 2007). The discrepancy between the results of these studies may be due to the diverse methods of measuring ED crowding.

Multiple studies have been performed that examine delays in cardiac intervention, measured in the minutes it takes from arrival to the ED to an intervention in the cardiac catheterization lab (Pelliccia, Cartoni, Verde, Salvini, Mercuro, & Tanzi, 2004; Singer, Shembekar, Visram, Schiller, Russo, Lawson, et al., 2007; Thatcher, Gilseth, & Adlis, 2003). The results of the studies agreed that ED initiatives directed towards decreasing the time to intervention resulted in a better outcome for the patients (Kurz, Babcock, Sinha, Tuppy, & Allegretti, 2007; Pelliccia, et al, 2004; Singer, et al, 2007; Thatcher, et al, 2003). However, none of the studies examined the impact that ED crowding has on the time to intervention in this population.
The effects of ED crowding on patient satisfaction levels (Bernstein, et al., 2009; Derlet & Richards, 2000; Francis, Spies, & Kerner, 2008), medication administration delays (Fee, Weber, Maak, & Bacchetti, 2007; Pines, Hollander, Datner, & Metlay, 2006), and mortality (Noor Mohammad, Grannis, & Finnell, 2008; Richardson, 2006; Sprivilus, Da Silva, Jacobs, Frazer, & Jelinek, 2006) are well documented. These studies demonstrate that quality of care may be impacted during crowding resulting in delays in treatment and medication administration, reduced patient satisfaction and even death. Unfortunately, ED crowding is a complex problem that require new and innovative solutions. Therefore, ED practitioners and administrators need more information about how to provide quality care despite ED crowding. One strategy is to prevent delays in treatment and decrease mortality by recognizing early warning signs that a patient is in distress, as well as rapidly responding to those warning signs.

Cost of ED Crowding

In addition to the patient satisfaction and the physiological impact on patients, ED crowding has a financial impact on hospitals and payers. Much of the research regarding the financial cost of ED crowding has been associated with the hospitals where crowding occurs. Such costs include opportunity losses from revenue from ambulance diversion, patients leaving without being seen, loss of returning patients due to decreased satisfaction scores, and incentives to recruit and retain staff exposed to the stressor of ED crowding.

Two articles were located that calculated the financial effect of ED crowding on the hospital. One study estimated that the hospital lost $204 in
potential revenue per patient with an extended ED boarding time and sustained an annual opportunity cost in lost hospital revenue for chest pain patients of $168,300 (Bayley, Schwartz, Shofer, Weiner, Sites, Traber, et al, 2005). Another study found that patients who boarded in the ED longer than a day stayed in the hospital longer which increased costs by an estimated $6.8 million during a 3 years period (Krochmal & Riley, 1994).

Ambulance diversion is another source of potential provider opportunity cost losses. One study found that during 1 in 8 patient transports, the ambulance could not unload the patient promptly at the ED, putting it out of service for 15 minutes or more (Eckstein & Chan, 2004). Another study reported that delays, due to ambulance diversion and the lack of available inpatient beds, required more staff and equipment to be used at a cost of $1 million per year in a single community (Schneider, Zwemer & Doniger, 2001).

The financial cost of ED crowding to payers has been demonstrated in a study that examines congestive heart failure patients admitted to the hospital. Those suffering from congestive heart failure with an ED stay of less than 8 hours averaged 3.2 days fewer in the hospital and accumulating charges of $15,773 less than those who stayed in the ED longer than 8 hours (Bayley, Schwartz, Shofer, Weiner, Sites, Traber, et al, 2005). Similarly, patients with altered mental status, who stayed in the ED over 8 hours, ended up staying in the hospital 2 days longer and accrued $20,510 more in charges than those that were in the ED less than 8 hours (Bayley, Schwartz, Shofer, Weiner, Sites, Traber, et al, 2005).
The Role of the Emergency Nurse

The role of the emergency nurse is multi-factorial. Some of the basic roles of the emergency nurse are to (a) collect, interpret and document vital signs of patients in the ED, (b) identify normal and abnormal data, (c) question abnormal data, and (d) notify the physician about abnormal findings. This role has been shown to be critical to providing quality care to patients. Research demonstrates that the deterioration of patients is frequently preceded by documented deterioration of physiological measures (Sax & Charlson, 1987; Smith & Wood, 1998). Additionally, suboptimal care and improper reactions to abnormal findings may be linked to increased mortality (McGloin, Adams & Singer, 1999; McQuillan, Pilkington, Allan, Taylor, Short, Morgan et al., 1998). Early warning signs of deterioration, as measured by vital signs, provide clues to a patient’s condition. There are no published data regarding how the collection and interpretation of vital signs has affected the quality of care during periods of crowding.

Problem statement

The problem was that much of the ED crowding research focused on single factor outcomes that result from delays in diagnosis or treatment. However, we have limited information about discernment of clues that precede catastrophic outcomes. Nor do we know if crowding contributes to increased or decreased vigilance and reporting/communicating in the presence of clues. Current research does not provide information of the effect that ED crowding has on the quality of care provided to ED patients by nurses.
Theoretical Framework

Although there was no consensus on the terminology and definition, there appeared to be consensus as to a conceptual model of the causes of ED crowding. Researchers agree that several factors consistently contribute to ED crowding: (a) fewer hospitals nationwide, (b) nursing staff shortages, (c) decreased inpatient beds, (d) increased patient volume, (e) increased acuity of patients entering the ED, and (f) increased number of patients boarded in the ED (Bernstein, Verghese, Leung, Lunney, & Perez, 2003; Estey, et al, 2003; Magid, et al, 2004; Raj, Baker, Brierley, & Murray, 2006). Because few of these factors are amenable to interventions, (e.g. it is unlikely that new hospitals will be built, inpatient beds added to hospitals, or that acuity will suddenly decrease) it may be that effective strategies for the optimization of patient outcomes to focus on the processes that contribute to maintaining high quality care even during times of crowding.

A conceptual model, developed by Asplin, Flottemesch and Gordon (2006), groups factors that contribute to crowding into the three categories of input, throughput and output (see Figure 1). Input refers to factors that precede the patient’s ED visit; such factors include the aging population, availability of alternate treatment sites, insurance status, and the patient’s reason for seeking treatment. Throughput focuses on the operations within the ED such as staffing, the physical layout of the ED, the availability of services, and departmental protocols. Output factors refer to the ability to transfer or discharge patients out of the ED. Complications in any of these categories may cause increases in the ED
nurse’s workload and perceived decreases in the quality of patient care (Magid, et al, 2004). Although this model addresses issues that affect crowding in the ED, this model does not address the concept of quality of care. While there are several conceptual models describing the causes of ED crowding, no model was located that related ED crowding to quality of care measures.

Figure 1. Asplin et al (2003) Model of ED Crowding

In an attempt to understand the causes and implications of ED crowding, research on the topic continues to be produced. In the last 20 years, the rate of articles published regarding ED crowding has increased dramatically every year. A search on Pub Med for the terms ‘ED’ or ‘emergency department’ with ‘overcrowding’ or ‘crowding’ produced 95 research articles. The majority of the articles examined the development and evaluation of instruments attempting to measure ED crowding (Bernstein, Verghese, Leung, Lunney, & Perez, 2003; Hoot, Zhou, Jones, & Aronsky, 2007; Jones, Allen, Flottemesch, & Welch, 2006; Weiss, Derlet, Arndahl, Ernst, Richards, Fernandez-Fracketton, et al., 2004; Weiss, Ernst, Sills, Quinn, Johnson, & Nick, 2007). Several other articles examined the potential causes of crowding (Estey, Ness, Saunders, Alibhai, & Bear, 2003; Hoot, & Aronsky, 2006; Magid, Asplin, & Wears, 2004; May &
Grubbs, 2002; Richardson, Ardagh, & Hider, 2006). Only nine articles examined the relationship of ED crowding to patient outcomes. Outcome measures are quality measures that describe the impact on health resulting from care provided by the health care system (Center for Medicare and Medicaid Services, 2007). The outcomes investigated in the located articles include pain management, antibiotic administration, and mortality (Christopher, Ellen, Carley, & Peter, 2007; Hwang, Graff, Radford, & Krumholz, 2004; Jesse, & Judd, 2008; Sprivilis, Da Silva, Jacobs, Frazer, & Jelinek, 2006).

Much of the research regarding ED crowding was at an organizational level. Urgent Matters, a division of the Robert Wood Johnson Foundation, has become the leading organization in ED crowding research and has focused upon finding best practices for hospitals to address ED crowding. Urgent Matters was focusing their resources on the Input and Throughput aspects of the Input/Throughput/Output model (see Figure 1) with little attention being paid to output issues and the effect that ED crowding has on outcomes.

One of the major difficulties with using the Input/Throughput/Output model in this study was the measurement of the output. The focus of the ‘output’ section of this model only examines the physical location of patients at the end of their ED visit. There are three main locations for output (a) death, (b) hospital admission, and (c) community discharge. While the Input/Throughput/Output model provides a thorough picture of the causes of ED crowding, it does not provide an assessment of the provision of care offered during crowding or alternate patient outcomes.
Much of the research available on the effects of ED crowding uses mortality as an outcome measure (Fatovich, 2005; Pham, Patel, Millin, Kirsch, & Chanmugam, 2006). However, to understand the implications of ED crowding on patients, other outcomes may need to be examined to maintain optimal care. A quality improvement model could be implemented to look at degrees of which outcomes change in relation to the degree of ED crowding. Quality improvement models have been used extensively in EDs. However, much of the research has been used for intra-organizational purposes and has not been published. The research that has been published addresses a diversity of topics. The majority of the most recent articles that focus on quality improvement in the ED describe the change made within the ED and the effect that it has had on throughput, output, and crowding levels (Francis, Spies, & Kerner, 2008; Howell, Bessman, Kravet, Kolodner, Marshall, & Wright, 2008; Welch, & Allen, 2006).

Mortality was a common patient outcome measure and has been used as an indicator of quality of care. The current leaders in ED crowding research frequently use death as a measure of adverse patient outcomes (Urgent Matters, 2004). However, death is a dichotomous variable. Either the patient experiences death or s/he does not. This does not represent the full spectrum of potential outcomes that an ED patient could experience. To obtain a more precise picture of the true effects of ED crowding on patients, a broader spectrum of patients’ outcomes was required.

In quality evaluation, death was also one of the common and early indicators of the quality of care. However, studies have shown that using
complication rates was a better measure of quality than death (Silber, Rosenbaum, Schwartz, Ross, & Williams, 1995). By examining complications, delays in care delivery and associated adverse outcomes, researchers can better evaluate ED crowding and develop interventions that target processes of care to optimize treatment when crowding occurs.

For example, many studies that examined the effects of ED crowding measure delays in dispensing medication, such as antibiotic administration (Barrett & Schriger, 2008; Fee, Weber, Maak, & Bacchetti, 2007; Pines, Hollander, Datner, & Metlay, 2006; Pines, Hollander, Localio, & Metlay, 2006; Pines, Localio, Hollander, Baxt, Lee, Phillips, et al., 2007), analgesia (Ducharme, Tanabe, Homel, Miner, Chang, Lee, et al., 2008; Hwang, Richardson, Sonuyi, & Morrison, 2006) and thrombolytics (Schull, Morrison, Vermeulen, & Redelmeier, 2003). Such delays have been shown to have effects on patients that range from inconvenient to severe health impairment. Delays in analgesics lead to undue suffering in patients with severe pain (Barrett & Schriger, 2008), hip fractures (Hwang, Richardson, Sonuyi, & Morrison, 2006), and other extremity injuries (Abbuhl & Reed, 2003). Delays in the administration of aspirin and thrombolytic medications have been shown to have an impact upon the severity of myocardial damage (Reikvam & Aursnes, 1999) and cerebrovascular accident patients (Roden-Jullig, Britton, Malmkvist, & Leijd, 2003).

The degree of harm due to delays in antibiotic administration depends on the patients’ presenting diagnosis. Antibiotics are used in the ED to treat infections ranging from sexually transmitted diseases and otitis media, to
meningitis and pneumonia. A delay in the administration of an antibiotic for an ear infection carries a less severe implication than a potentially life threatening diagnosis of bacterial meningitis. Delays have been associated with increased length of stay in patients diagnosed with community acquired pneumonia (Blot, et al., 2007) and mortality in meningococcal disease (Bugden, Coles, & Mills, 2004).

However, it is believed that these delays can be reduced. Adverse outcomes caused by delays can be minimized by decreasing the time to correctly diagnose patients, streamlining care, improving communication and providing prompt treatments. These interventions are crucial to minimizing adverse outcomes in at-risk patients.

Other measures of effects of ED crowding on patients are limited. Studies of medication errors in the ED are confounded by underreporting by staff (Croskerry, & Sinclair, 2001; Francis, Spies, & Kerner, 2008; Horwitz, Meredith, Schuur, Shah, Kulkarni, & Jenq, 2008; Hostetler, Mace, Brown, Finkler, Hernandez, Krug, et al., 2007; O'Neill, Shinn, Starr, & Kelley, 2004; Trzeciak, & Rivers, 2003). Failure-to-rescue, a nurse-sensitive outcome, has been associated with early recognition of abnormal vital signs but all studies that used this as a measure of quality only examined surgical patients and did not include ED patients (Schmid, Hoffman, Happ, Wolf DeVita, et al., 2007).

Quality improvement (QI) models are used to examine ways to improve a process. QI projects look for ways to make a process simultaneously faster, cheaper and better. However, high quality is the main focus of the projects and ideally should not be compromised to make the process less expensive or more
expedient. QI has been adapted by most healthcare organizations because successful QI projects save the organization money while maintaining, or improving, patient outcomes.

Although Asplin’s model provides an acceptable model of the causes of ED crowding, it does not capture how quality of care is affected by crowding. The addition of potential mediators and moderators that may be present during ED crowding would allow the model to evaluate patient care factors. Asplin’s model is derived from a medical point of view; to make this model applicable to nursing application it is believed that nursing processes should be added. Nursing care is represented within the arrows that connect the concepts of Input, Throughput and Output in the model (see Figure 2). The arrow between Input and Throughput represents triage, between Throughput and Output represents the discharge process and the long arrow between Input and Output represents the nursing care that patients receive while in the ED.

Figure 2. Modification to Asplin model

Measuring Quality
Donabedian explains that the criteria of quality are “nothing more than value judgments that are applied to several aspects, properties, ingredients or dimensions of a process” (Donabedian, 2005, p. 692). Klein, Malone, Bennis and Berkowitz (1961) concluded that patient care cannot be considered as a unitary concept and that “there will never be a single comprehensive criterion by which to measure the quality of patient care.” Therefore, it is assumed that the criteria selected by researchers in order to assess the quality of care will have a profound influence on the approach that the researcher chooses to examine a phenomenon of interest. Donabedian presents a model composed of three interrelated components that can be used to assess quality: structure, process, and outcome (see Figure 3).

Figure 3. Donabedian Structure-Process-Outcome

*Measuring quality by structure.* Quality can be assessed by examining the structure of an area to be studied. This can include the location where the study is occurring or administrative and related processes that support and direct the
provision of care, such as staffing procedures, managerial methods or any of a number of support services within a hospital (Donabedian, 2005). Other considerations that may be included in the category of structure pertain to the adequacy of facilities and equipment as well as qualifications and/or education of medical and nursing staff. Measuring quality by examining structure assumes that with proper equipment and facilities good care will follow (Donabedian, 2005). Because the relationship between structure and process or outcomes is generally not well established, it was determined that assessing quality by examining structure alone was not the best approach for this study.

Measuring quality by process. Quality can be measured through examining the process of care. This is done when the researcher’s interest is not focused on achieving results from an intervention, but rather to judge whether high quality of care has been provided (Donabedian, 2005, 694). Such judgments can be made based on appropriateness, completeness and redundancy of the information obtained about a patient. However, Donabedian (2005) explains that although these assessments may be more relevant to the subject being studied, the “estimates of quality that one obtains are less stable and less final than those that derive from the measure of outcomes”.

Measuring quality by outcomes. As mentioned previously, mortality is often used as an indicator of quality for several reasons. The validity of mortality as an outcome and a measure of quality is rarely challenged. Mortality is a stable measure, a change from that state does not occur and therefore death is also a precise measure. Finally, mortality is easy to measure and define. This may be
the main reason why research has focused on mortality as a measure of the impact of ED crowding.

However, there are limitations to using mortality as an outcome measure. At times, mortality may not be a relevant measure of quality. Factors other than the quality of care provided may have an impact on mortality rates. Such is the case when a patient enters the ED with a terminal illness. Generally mortality has been considered a poor outcome. However, when a terminally ill cancer patient enters the ED with the wish to have a peaceful, pain free death, the outcome (e.g. death) may reflect poorly on the mortality rate of the ED while simultaneously illustrating the best possible care (e.g. process) that could have been provided to the patient as well as a desired outcome.

Other outcomes for measuring quality are less clearly defined and more difficult to measure. Such variables include satisfaction, attitudes and perceptions of quality of care. These variables are more subjective in nature and may vary based on ethnicity, geographic area and severity of illness of the patient (Donabedian, 1985). It is possible that vital sign frequency can affect outcomes by preventing death, providing patient-staff interaction and supporting perception of competency, all activities with potential links to satisfaction with care quality.

By using the structure of the modification of Asplin’s model of ED crowding, and incorporating Donabedian’s focus on processes and outcomes, a conceptual model for this study was designed (see Figure 4). However, only part of the model created for this study was tested (see Figure 5). The research questions for this study were taken from the Input and Throughput sections and
the Triage and Nursing Care processes described in the model. Table 1 shows the study variables used to measure concepts in the model. Figure 6 depicts the hypothesized relationships between the study variables.

![Figure 4. Modified Model of ED Crowding](image)

![Figure 5. Tested portion on of modified model of ED crowding](image)
<table>
<thead>
<tr>
<th>Input</th>
<th>Triage</th>
<th>Throughput</th>
<th>Nursing Care</th>
<th>Crowding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Prescription Medications</td>
<td>Triage Category</td>
<td>Length of Time between Vital sign Recordings</td>
<td>Number of Routes of Medications Administered in ED</td>
<td>EDWIN</td>
</tr>
<tr>
<td>Number of OTC Medications</td>
<td></td>
<td>Length of Stay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Presence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insurance Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marital Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival in Private Car</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Substraction of Theoretical framework

To clarify the relationship between the variables that were included in the model and the broader concepts within the theoretical model, a substraction of the model was created (see Figure 7). The variables that were used to for each
concept are located under the concept heading. The three concepts were taken directly from the theoretical model used to guide this study (Figure 4).

Figure 7. Substraction of Theoretical Model

**Vital Signs**

One of the most common tasks of an emergency nurse is to assess the vital signs of their patients. Vital signs provide rich sources of information on a patient’s condition and are commonly obtained in triage, routine nursing assessments, throughout the continued monitoring of patients and at the time of discharge. Vital signs, or signs of life, were so named because they provide interpretable information as to the vital state of the patient. Vital signs are easily obtained by nursing staff and obtaining them can be accomplished regardless of the patient’s level of consciousness.

The number of components that make up the collective term of vital signs varies. Four measures are typically included in vital sign reporting: (a)
temperature, (b) heart rate or pulse, (c) respiratory rate, and (d) blood pressure. The subjective measurement of pain is often referred to as the fifth vital sign (Walid, Donahue, Darmohray, Hyer & Robinson, 2008). The sixth measure included in the reporting of vital signs is pulse oximetry or peripheral oxygenation.

Temperature. Body temperature (T), is a measure of the body’s ability to generate and get rid of heat (Medline Plus, 2009). There are three states a person can be in related to body temperature: hypothermic, normothermic, and hyperthermic.

Hypothermia is defined as a body temperature below 35°C (95°F) (Marx, Hockberger, Walls, 2006). Hypothermia occurs when more heat is lost than the body can generate. This state usually occurs due to extended exposure to the cold or inability to keep up a metabolic rate. Hypothermia can lead to lethargy, cardiac arrest, shock, coma and death (Auerbach, Davis & Phillips, 2001).

Hyperthermia, also called pyrexia or fever, is considered when the body temperature of an adult reaches or exceeds 100.5°F (>38°C) (Marx, Hockberger, Walls, 2002). The potential causes of hyperthermia are numerous and include infections (viral or bacterial), drugs or toxins, severe trauma, autoimmune diseases, some cancers and extended exposure to an external heat source (Marx, Hockberger, Walls, 2002).

The definition of normal body temperature varies. It has been identified as greater than hypothermic and less than hyperthermic and from 35°C (95°F) to 38°C (100.4°F). According to Medline Plus (2009), the average normal body
temperature is 37 degrees Celsius (98.6 degrees Fahrenheit) but can vary by 0.6°C (1°F). Normal body temperature varies due to age, menstruation and time of day. However, temperature varies less in adults than children. According to the encyclopedia of Surgery (2008), normal body temperature taken orally is 98.6°F (37°C), with a range of 97.8–99.1°F (36.5–37.2°C).

Heart rate. Heart rate (HR), or pulse, is an important vital sign that is a measurement of the number of contractions of the ventricles of the heart per minute. Heart rate is different than heart rhythm in that in order to accurately determine a heart rhythm a cardiac monitor is required while HR can be determined by auscultation through a stethoscope or by manual palpation by applying pressure over an artery. Heart rate can be classified as normal, slow (bradycardia), or fast (tachycardia).

Bradycardia is defined as a heart rate below 60 beats per minute (bpm) in adults. Bradycardia may be normal in athletes or patients on medications such as beta-blockers, but may be an indication of an acute MI, Acute Coronary Syndrome or an electrical conduction problem within the heart, any of which may lead to death (AHA, 2006). Because patients suffering from bradycardia may not be symptomatic, HR is an important measure in detecting many life threatening conditions.

Tachycardia is defined as a heart rate greater than 100 bpm. Some common causes of tachycardia are fever, hypovolemia, anxiety, hyperthyroidism and normal exercise (AHA, 2006). Uncontrolled tachycardia can cause
inadequate tissue perfusion due to insufficient ventricular filling time leading to cardiac arrest or death (AHA, 2006).

A heart rate is considered normal when it ranges between 60 and 100 bpm but may vary based on gender, age, fitness level, daily medications and genetics (Seidel, Ball, Dains, & Benedict, 2003). Because both bradycardia and tachycardia can result in adverse outcomes, it is apparent why heart rate is such an important vital sign.

*Respiratory rate.* Respiratory rate (RR) is the number of breaths inhaled per minute and is usually measured by observing the number of times a patient’s chest rises in a minute. Respiratory rate may be the most controversial of all the vital signs. Respiratory rates are often assessed inaccurately (Lovett et al., 2005). However, studies have demonstrated that the manual measurement of respiratory rate appears to be reliable (Worster, Elliott, Bose, & Chemeris, 2003). Respiratory rates may be classified as normal (RR >12 and <20), tachypnea (RR > 20 breaths/minute), bradypnea (RR < 12 breaths/minute) or apnea (RR=0). Tachypnea is associated with cardiac arrhythmias, amphetamine abuse, an acidotic state, traumatic brain injury, anxiety, asthma and other causes of respiratory inflammation while bradypnea is associated with shock, head injury/skull fracture, alkalosis, and hypothermia (Seidel, Ball, Dains, & Benedict, 2003).

*Blood pressure.* Blood pressure (BP), measured in millimeters of mercury (mmHg), is the pressure exerted on the walls of blood vessels by circulating blood (Seidel, Ball, Dains, & Benedict, 2003). The two components that
determine BP are the systolic and diastolic measures. Systolic blood pressure (SBP) is the amount of pressure exerted on the blood vessels during the contraction of the ventricles of the heart (Medline Plus, 2009). Diastolic blood pressure (DBP) is the amount of pressure exerted on blood vessels during the period of time when the ventricles are at rest (Seidel, Ball, Dains, & Benedict, 2003). Adult BP can be described in one of four categories: hypotensive (SBP <90 or DBP <60), normotensive (SBP between 90-119 and DBP between 60-79), prehypertensive (SBP between 120-139 or DBP between 80-89), or hypertensive (SBP ≥140 or DBP≥90) (Chobanian, Bakris, Black, Cushman, Green, Izzo, et al., 2003). Blood pressures fluctuate normally throughout the day. However pressures outside of the normotensive range may be indicative of underlying health conditions. Hypertension may be a chronic condition or situational due to anxiety or fear. Due to the risks associated with hypertension, patients may present to the ED suffering from MI, heart failure, cerebrovascular accidents or arterial aneurysms. Symptoms associated with hypertension are headache, tinnitus, dizziness, confusion, fatigue, nose bleeds or heart palpitations (Seidel, Ball, Dains, & Benedict, 2003). Hypotension may indicate that a patient is (a) in a state of hypovolemia, (b) having side effects from a medication (e.g. antidepressants), (c) abnormal stimulation of the vagus nerve or (d) shock. Symptoms associated with hypotension are dizziness, angina, or fainting.

**Peripheral oxygenation.** Peripheral oxygenation (SpO2) or hemoglobin saturation is routinely measured by placing a pulse oximeter on the patient’s finger. This vital sign is defined as the amount of oxygen being carried in the red
blood cells. Normal SpO2 level are greater than 92% saturation. A SpO2 level less than 90% may be indicative of chronic obstructive pulmonary disease, sleep apnea, asthma, pneumonia, respiratory insufficiency and anemia. Low SpO2 levels can cause cyanosis, anxiety, decreased level of consciousness, confusion and death.

Composite vital signs. Although each vital sign is important in assessing a patient’s condition, a composite vital sign measure may be a better indicator of the true condition of a patient’s health. Composite vital signs may provide a more holistic description of a patient at risk or that is experiencing important impaired health or catastrophic derangement.

Monitoring Vital Signs

Research demonstrates that crowding increases stress in both patients and staff in the ED (Lloyd, 1994). During periods of stress, the sympathetic nervous system is activated which prepares the body for “fight or flight” which causes changes in several components of vital signs (e.g. accelerated heart and respiratory rate and elevated blood pressure). In addition, stress hormones can increase pain sensation. Contextual factors can suggest a need for frequent monitoring despite normal vital signs or infrequent monitoring despite abnormal vital sign values. Obtaining contextual factors was beyond the scope of this retrospective chart audit project. However, documentation in nurse’s narrative notes were examined and collected in a subset of the sample to provide guidance for future, prospective studies. Teaching discernment of vital signs is a potential intervention to improve quality care regardless of ED crowding.
Vital signs have been used to determine early warning signs of patient deterioration (Tarassenko, Hann & Young, 2006). For example, vital signs have been shown to be reliable predictors of the need for life-saving interventions in trauma patients (Holcomb, Salinas, McManus, Miller, Cooke & Convertino, 2005). Standards of care have not been established that provide guidelines for the frequency of obtaining vital signs in the ED. The recommended frequency of obtaining vital signs depends on the patient’s acuity level, chief complaint and hospital policy. No research has been published that examines the frequency of, and the nurse’s response to vital signs by emergency nurses during periods of crowding.

Research questions

RQ1. Was there an association between the length of time between vital signs recording and differing degrees of ED crowding?

RQ2. On days when the ED was crowded, what factors influenced the frequency with which emergency nurses monitored patients’ vital signs?

RQ3. What factors influenced the time to the emergency nurse’s initial response when abnormal vital signs were present?

RQ4. What effect did the degree of ED crowding have on the measurement of vital signs for a patient in the ED?

Significance of study

Significance to Nursing Science

Nursing science is the accumulation of scientific knowledge that makes nursing unique (Barrett, 1997). This study will advance nursing practice by
adding to the nursing body of knowledge an understanding of how ED crowding affects the quality of care provided by the emergency nurse. This study will help evaluate factors and potential barriers to the emergency nurses’ safe, effective monitoring. Findings from this study may provide evidence-based knowledge for future studies regarding safe patient care during times of ED crowding.

**Significance to Nursing Discipline**

A discipline is “characterized by a unique perspective, a distinct way of viewing all phenomena” (Donaldson & Crowley, 1978). Much of the crowding research has been generated by physicians and policy makers and lacks the unique perspective that nurse researchers provide. Studies conducted within the medical profession focus on how to fix the problem of ED crowding and not on how the problem affects the safe delivery of care. This is especially important as more people depend on the ED for care while the numbers of EDs decrease causing crowding to most likely increase (Bernstein, Verghese, Leung, Lunney & Perez, 2003). Discovering empirical evidence that ED crowding affects patients and nurses will add to the growing volume of nursing’s body of knowledge and will provide a basis for theory generation within the nursing discipline. By modeling studies within the nursing discipline, nurse researchers can use their unique contribution to healthcare and enhance nursing as a scholarly discipline (Barrett, 1997).

The proposed study contributes to the nursing discipline by addressing all of the components of the nursing metaparadigm: health, nursing, person and environment. Just as Florence Nightingale was the first nurse to identify the
importance of these interactions between an individual and their environment, this nursing study has begun to examine how nurses and patients are affected by ED crowding within the nursing paradigm. This project has added to the body of nursing knowledge and has allowed researchers to begin to examine how health, environment, nursing and persons are affected by the global problem of ED crowding.

**Significance to Nursing Policy and Practice**

ED crowding is common and recurrent in emergency nursing practice. Policy makers have been mandated by the JC to address crowding issues and the implementation of such policies has had a direct impact on how the emergency nurse is required to practice. Florence Nightingale (2003) wrote that the role of nursing practice is “to put the patient in the best possible condition for nature to act upon him”. This declaration has guided nursing practice to focus on improving quality of care while meeting the mandated practice standards of regulation agencies by providing an atmosphere of healing for patients. This study will examine possible correlations between the different degrees of ED crowding and the monitoring of vital signs. The results of this study provide evidence that supports developing or revisiting nursing practices and policies related to the actions of the emergency nurse during times of crowding (LiBiondo-Wood & Haver, 2002).

**Assumptions**

Based on the theoretical underpinnings, the assumptions for this study included the following:
1. The emergency nurse’s role is both collaborative and independent.
2. Some interventions, such as monitoring for responses to therapy can be performed without specific orders from emergency physicians.
3. Documented interventions occur at the time noted on the chart.
4. An undocumented observation or intervention is a nursing act that has not been performed.
5. Vital signs that are not recorded have not been acknowledged by the emergency nurse.

Definition of Terms

The conceptual and operational definitions of the study variables are as follows:

Exogenous Variables

ED crowding

*Conceptual Definition:* Any time when inadequate resources to meet patient care demands lead to a reduction in the quality of care

*Operational Definition:* An EDWIN score of 2.0 or higher

Age

*Conceptual Definition:* The number of years that a person has existed

*Operational Definition:* The number of years recorded on the patient’s registration sheet.

Gender

*Conceptual Definition:* Either of two categories (male, female) into which an organism is divided.
**Operational Definition:** The sex recorded by the registration clerk on the registration sheet.

**Payment method**

*Conceptual Definition:* The source of funding that reimburses the hospital for services rendered to the patient.

*Operational Definition:* The category of payment (i.e. Medicare, Medicaid, private insurance, self pay) reported by the patient and recorded by the registration clerk on the registration sheet.

**Ethnicity**

*Conceptual Definition:* An affiliation resulting from racial or cultural ties

*Operational Definition:* A race (i.e. Caucasian, African American, Hispanic, Asian, other) recorded by the registration clerk on the registration sheet.

**Mode of arrival**

*Conceptual Definition:* The mechanism of transportation that brought the patient to the ED.

*Operational Definition:* The mechanism of transportation (i.e. ambulance, private car, police escort, other) that brought the person to the ED as recorded by the nurse on the triage sheet.

**Waiting time**

*Conceptual Definition:* An indirect measure of the length of time from triage until bed assignment within the ED.
**Operational Definition:** The difference in minutes between the recorded time of the triage assessment and the recorded time of ED room assignment.

**Family presence**

Conceptual Definition: Any person accompanying the patient in the ED.

Operational Definition: Any note of friend, spouse, sibling or companion present during the patients stay in the ED.

**Admission diagnosis**

Conceptual Definition: The patient’s presenting complaint.

Operational Definition: The patient’s presenting complaint as documented during the triage assessment. This will be categorized by systems (cardiovascular, musculoskeletal, pulmonary, neurological, gastrointestinal, multiple system trauma, renal/urinary, gynecological, psychological, endocrine)

**Comorbidities**

Conceptual Definition: A condition or diagnosis that impacts health.

Operational Definition: A list of conditions noted by a medical professional within the patient’s ED chart.

**Triage category**

Conceptual Definition: The level of acuity

Operational Definition: The score of 1-5 of the Emergency Severity Index version 4 where 1 is the highest acuity and 5 is the least acute.
**Number of routes of medications administered**

Conceptual Definition: All of the different methods that the patient received medication while present in the ED

Operational Definition: The sum of the number of routes medications were administered to the patient while being treated in the ED including, but not limited to intravenous, intramuscular, sublingual, subcutaneous, and oral.

**Abnormal vital signs**

Conceptual Definition: Values outside the normal range for temperature, heart rate, respiratory rate, blood pressure, peripheral oxygenation, pain

Operational Definition: temperature < 35.0 or > 38.5, heart rate < 51 or > 100, respiratory rate <9 or >14, blood pressure (SBP < 101 or > 199, DBP <60 or >90), peripheral oxygenation < 92%, pain > 4.

**Composite vital signs**

Conceptual Definition: A score composed of multiple components based on values for patient’s systolic blood pressure, heart rate, respiratory rate, temperature, and level of consciousness.

Operational Definition: The MEWS value

**Endogenous Variables**

**Length of time between vital signs recordings**

Conceptual Definition: The length of time between 2 or more vital sign recordings
Operational Definition: The minutes between vital signs as recorded in the ED chart

Emergency nurse’s initial response

Conceptual Definition: Any intervention related to abnormal vital signs

Operational Definition: The minutes between abnormal vital sign recording and an intervention (i.e. physician order, medication administration, oxygen administration/adjustment, recorded call to physician, respiratory therapist or pharmacist, repositioning) located in the flow sheet, narrative notes, and medication administration record or physician order sheet.
Chapter Two

Literature Review

This chapter reviews the theory and empiric data that defines ED crowding and contributes to a framework associating ED crowding and adverse patient outcomes. Additionally, the literature examining the recognition and communication of vital signs by nurses was reviewed. Obtaining vital signs is a common nursing intervention; not recognizing or responding to clinically important changes in heart rate, blood pressure, respiratory rate, temperature or peripheral oxygenation can lead to adverse patient outcomes especially in acute care settings (Cioffi, Salter, Wilkes, Vonu-Boriceanu, & Scott, 2006; Horwitz, et al., 2008; Teixeira, et al., 2007). When crowding in the ED occurs, it is possible that adverse patient outcomes occur as a result of missed cues in patient vital signs.

ED Crowding

History

ED crowding was first described in 1989 (Dickinson, 1989). Because of the unscheduled nature of ED patients’ visits, periods of crowding have always been present. For example, EDs have had periodic crowding because of motor vehicle accidents on cold mornings due to icy roads or because of cold and flu season. However, the current problem of crowding in the ED is not due to the normal ebbs and flow of environmental influences of accidents or illness outbreaks. ED crowding has become a chronic problem. Both the passage of the Emergency Medical Treatment and Active Labor Act which mandated that EDs
provide a screening exam and stabilization for all presenting patients regardless of the ability to pay and the increased use of the ED due to the growing rate of uninsured Americans, have increased the utilization of, and the demands made upon, ED services (Bernstein & Asplin, 2006). As the annual number of visits to the ED rose 23% from 89.8 million to 110.2 million between 1992 to 2001, the number of EDs shrank from 5169 in 1988 to 4037 in 2002 (Burt & McCaig, 2001; McCaig & Burt, 2004).

**Definition**

The complex task of fixing the problem of ED crowding is made more difficult by the lack of a consistent definition and terminology for ED crowding. Researchers are divided on whether to label the problem as ED crowding or ED overcrowding and whether the two terms are degrees of the same problem. In 2003, Asplin et al. called for a paradigm shift that modified the accepted terminology of ‘ED overcrowding’ to a broader concept of ‘ED crowding’ in order to emphasize that overcrowding is simply one condition within the crowding scale.

Although there have been numerous articles written on ED crowding, there has been a lack of agreement as to the definition of ED crowding (Asplin, Magid, Rhodes, Solberg, Lurie & Camargo, 2004). Several definitions have been proposed to describe ED crowding. Other definitions include the presence of extensive waiting room times, nurse and physician perceptions of crowding, the number of high acuity patients, the presence of admitted patients boarded in the ED, the occurrence of ambulance diversion, and the increased ratio of staff
including both nursing and medical personnel to patients. However, the most common definition used in the current research is when the percent of ED beds occupied ranges from 75% to 100% of occupancy.

There are several acceptable measurements of ED crowding. Richardson (2006) measured ED crowding as patient occupancy at, or greater than, the 75\textsuperscript{th} percentile for a given time period. Although Richardson’s definition is simple to calculate, many researchers believe that it does not capture the multiple facets of ED crowding (ACEP, 2002; Asplin, Magid, Rhodes, Solberg, Lurie, & Camargo, 2003).

Other researchers have based their measurements of crowding on the criteria created by the Crowding Resources Task Force of 2002. According to the Task Force, this situation occurs when the number of ED patients outnumbers the staffed ED treatment beds and wait times exceed a reasonable period (ACEP, 2002). The conceptual definition of ED crowding that will be used for this study was coined by Pines (2007) when he amended the definition created by the Crowding Resources Task Force to be quantifiable by defining ED crowding as any time when “inadequate resources to meet patient care demands lead to a reduction in the quality of care”.

There are many resources within the ED that may become overwhelmed and therefore deemed inadequate. Inadequate provider resources may occur due to decreased staffing, high nurse to patient ratios, excessive number of patients, the occurrence of a trauma team where many staff members are used to care for a single patient, or lack of available physicians. Limited physical space
is another example of inadequate resources. This restriction can be seen when patients are treated in areas that are normally not used to render care (e.g. hallways) or when patients are left to wait in the waiting room because there is no more space to treat them within the ED. Inadequate physical resources occurs when supplies, such as infusion pumps or heart monitors, are unavailable to care for the patients in the ED. Two measures of ED crowding were located that incorporate both occupancy and resource use; these approaches are briefly described.

The National Emergency Department Over-Crowding Study (NEDOCS) has been accepted and used by many large emergency departments and provides a starting point for research in this area (Weiss, Derlet, Arndahl, Ernst, Richards, Fernandez-Frackelton, et al., 2004). The NEDOCS has been developed as an online calculator (Weiss, 2004). This calculator uses an algorithm to assign a crowding score to the ED. Number of ED beds, number of hospital beds, total patients in the ED, number of ventilators in the ED, longest admit time (in hours) total admits in the ED, and waiting room wait time for the last patient called (in hours) are placed into the calculator and assigned a crowding level.

The Emergency Department Work Index (EDWIN) incorporates significant components of the Input/Throughput/Output model such as the number of patients in the ED, acuity levels, numbers of physicians on duty, and bed availability, into a single omnibus index. In one study, the EDWIN correlated well
with nurse and physician assessments of crowding (Bernstein, Verghese, Leung, Lunney & Perez, 2003).

**Conceptual Model of ED Crowding**

Currently, there are no conceptual models that develop relationships between ED crowding with quality of care measures.

**Causes**

The earliest studies examining ED crowding, or overcrowding, explored its root causes. Mistakenly, improper use of the ED and a growing population were identified as the cause of ED crowding. Recent research shows that output factors were more commonly associated with ED crowding. These identified causes include deceases in the number of ED facilities, decreases in the availability of inpatient beds, and boarding patients in the ED (Moskop, Sklar, Geiderman, Schears, & Bookman, 2008). Numerous articles examined the potential causes of crowding (Estey, Ness, Saunders, Alibhai, & Bear, 2003; Hoot, & Aronsky, 2006; Magid, Asplin, & Wears, 2004; May & Grubbs, 2002; Richardson, Ardagh, & Hider, 2006). Researchers agree that several of the factors that consistently contribute to ED crowding are fewer Emergency Departments nationwide, decreased nursing staff, decreased inpatient beds, increased patient volume, increased acuity of patients entering the ED, and increased number of patients boarded in the ED (Bernstein, Verghese, Leung, Lunney, & Perez, 2003; Estey, Ness, Saunders, Alibhai, & Bear, 2003; Magid, Asplin, & Wears, 2004; Raj, Baker, Brierley, & Murray, 2006). A conceptual model, developed by Asplin, Flottemesch and Gordon (2006), groups these
factors into the three categories: Input, Throughput and Output (see Figure 1). Input refers to factors that precede the patient’s ED visit. Input factors include the aging population, availability of alternate treatment sites, insurance status, and the patient’s reason for seeking treatment. Throughput focuses on the operations within the ED such as staffing, the physical layout of the ED, the availability of services, and departmental protocols. Output factors refer to the ability to transfer or discharge patients out of the ED. Complications in any of these categories have been shown to cause increases in the ED nurse’s workload and perceived decreases in the quality of patient care (Magid, Asplin, & Wears, 2004). Not until the causes of ED crowding had been identified and verified through replicated studies, did researchers begin to examine the effects that ED crowding had on patients, physicians, nurses and the community.

**ED Crowding and Adverse Outcomes**

In the last 20 years, the number of articles focusing on ED crowding has increased dramatically. A search on PubMed for the terms ‘ED’ or ‘emergency department’ with ‘crowding’ revealed a total of 270 articles. However, only 36 were research articles focusing on the measurement of ED crowding and its relationship to outcomes. Many of the articles examined the development and evaluation of instruments designed to measure ED crowding (Bernstein, Verghese, Leung, Lunney, & Perez, 2003; Hoot, Zhou, Jones, & Aronsky, 2007; Jones, Allen, Flottemesch, & Welch, 2006; Weiss, Derlet, Armdahl, Ernst, Richards, Fernandez-Frackelton, et al., 2004; Weiss, Ernst, Sills, Quinn, Johnson, & Nick, 2007). Of the 270 articles located, fifty-two were editorials
about ED crowding. Twenty-two discussed the development of potential measures of ED crowding while 92 examined the identified cause and potential solutions of ED crowding. Only twenty-one were research articles that examined the effects of ED crowding. In the identified research articles, ED crowding was associated with delays in antibiotic administration and pain management, increased mortality and decreased patient satisfaction. None of the studies were performed by nurses and most were conducted by the medical discipline and were descriptive in design.

*Decreased patient satisfaction.* Five research articles were located that examined the association between ED crowding and decreased patient satisfaction (McMullan & Veser, 2004; Pines, Garson, et al., 2007; Pines, et al., 2008; Vieth & Rhodes, 2006; Weiss, et al., 2005). The results of these studies consistently show an inverse relationship between patient/visitor satisfaction and identified components of ED crowding.

Weiss et al. (2005) used the rate of patients leaving without being seen as a measure of satisfaction while attempting to develop a quantifiable measure of ED crowding. In their prospective observational study, they hypothesized that the rate of patients leaving without being seen would be predicted by ED crowding as measured by the NEDOCS. Multivariate analysis was used to identify relationships within the data. For the two hundred and fourteen 2-hour periods, a correlation of 0.665 (p<0.05) was identified between the left without being seen (LWBS) rate and the NEDOCS score with the NEDOCS accounting for an $R^2$ of 0.43 (p<0.02).
Pines, Iyer, Disbot, Hollander, Shofer and Datner (2008) studied the association between factors related to ED crowding and patient satisfaction with the ED and the overall hospital. This retrospective cohort study examined the responses of 1,469 patients that completed a patient satisfaction survey over a 1-year period. Patients were asked about their satisfaction with registration, nursing staff, physician staff, explanation regarding delays and an overall recommendation about the ED. Each question was scored on a 5-point Likert scale (1 = very poor, 5 = very good). Because the question addressing the degree to which a patient would recommend the ED to others was the only question about the general ED visit, it was chosen as the primary outcome of the study. The elements of ED crowding that were measured included number of waiting room patients, ED occupancy as a percentage of treatment spaces, number of admitted patients. Ordinal logistic regression was used to analyze the data. ED hallway use was predictive of lower likelihood of recommending the ED (OR 0.8, 95% CI 0.6 to 1.0) and lower overall ED satisfaction (OR 0.7, 95% CI 0.5 to 0.9). Prolonged ED boarding times (OR 0.6, 95% CI 0.4 to 0.9) and prolonged treatment times (OR 0.6, 95% CI 0.4 to 0.8) were predictive of lower ED satisfaction. ED wait times (OR 0.5, 95% CI 0.3 to 0.7) were predictive of ED satisfaction. Although the authors provided valid arguments for the use of their measures of ED crowding, using a quantifiable measure of ED crowding would have made the study more generalizable. Additionally, if the authors had kept the outcome variables as continuous, the information obtained may have demonstrated relationships between degrees of ED crowding.
Antibiotic delay. Three studies were located that looked at the effect that ED crowding has on antibiotic administration (Fee, Weber, Maak, & Bacchetti, 2007; Pines, Hollander, Localio, & Metlay, 2006; Pines, Localio, et al., 2007).

Pines (2007) and his colleagues used a retrospective cohort study of 694 adults diagnosed with community-acquired pneumonia at a single, large urban academic ED over 27 months. The primary outcome was whether time from patient triage until antibiotic administration was less than or equal to 4 hours. Crowding was determined by two input measures (a) waiting room number at triage and (b) number of newly registered patients in the 6 hour period before triage. The 2 throughput measures included (a) arithmetic mean ED LOS for patients who were discharged from the ED in the 6-hours before triage and (b) arithmetic mean ED LOS for admitted patients who were transferred to inpatient beds in the 6-hours before triage. The 3 output measures included (a) the number of patients discharged from the ED in the 6-hours before triage, (b) the number of admitted patients who were transferred to inpatient beds in the 6-hours before triage, and (c) the boarding burden (total patient-care hours for those patients who had to be admitted to the hospital as determined by a computerized bed request). The 1 global measure of ED crowding was the total patient care measures (a sum of all hours for all patients currently treated in ED at triage). The main hypothesis for this study was that common measures of ED crowding would predict failure to deliver antibiotics in the ED within 4 hours. Multivariable regression and bootstrapping were used to test the adjusted impact of ED crowding measures of delayed or no antibiotic administration. Predicted
probabilities were calculated to assess the magnitude of the impact of ED crowding on the probability of delay or no antibiotics. Crowding was initially measured as a continuous variable but ultimately categorized the measures into quartiles for ease of presentation of effect size. However, limiting the variance of this variable decreases the strength of the study design. Because of risk of multicollinearity among crowding variables, collinear variables were dropped while variables with the best C statistic were kept. The researcher used bootstrapping with replacement to validate the model. The researcher assessed global goodness of fit using the Hosmer-Lemeshow test. Next, a predicted probability of the primary outcome for quartiles of individual crowding measures was calculated. Subsequently, the predicted probability at combinations of quartiles of crowding measures that were retained in the best multivariable model, adjusting for both patient and provider effects to determine an adjusted clinical effect of ED crowding on the primary outcome was calculated.

Although logistic regression is common in the medical literature, it does not provide data as rich as if the outcomes were not dichotomized. By requiring that the outcomes be discrete, one cannot know the full depth of the relationship that exists between the predictor variables and the outcome variable. This study may have provided a more thorough picture of the relationship between ED crowding levels and delays in antibiotic administration if another method of analysis had been used.

Increasing levels of ED crowding were associated with delays or no antibiotics administration. When the waiting room and recent length of stay were
both at the lowest quartiles, the predicted probability of delayed antibiotics within 4 hours was 31% when both were at the highest quartile; the predicted probability was 72%.

Chart selection method was not established but researchers did report inter-rater reliability (100%) on 5% (n=40). Because the study design is a retrospective cohort, the data used is limited by the data that can be located in the patient charts or hospital databases. Therefore, the possibility remains that confounders were not measured. One potential problem in data collection is that the nurses manually enter time of administration so there may be discrepancies between recorded time and actual time of administration. Because the researchers only examined one location, this study has limited generalizability. The authors explain that these crowding measures, chosen and adapted from a list of potential measures (Solberg, Asplin, Weinick & Magid, 2003) and assigned at triage, were chosen for their simplicity, ease of measure and face validity. However, there is no evidence that construct and content validity have been established in these measures.

Another study, led by Fee, used a cross-sectional study design and compared demographics and characteristics of 405 patients diagnosed with community acquired pneumonia for which antibiotic administration times could not be determined with those that could (Fee, Weber, Maak, & Baccetti, 2007). The researchers calculated time of arrival to antibiotic administration and dichotomized patients into those who did and did not receive antibiotics within 4 hours. The authors determined the number of patients in the ED at the time of
each pneumonia patient’s arrival. Then the patients were dichotomized into those who did and did not receive antibiotics within 4 hours. They hypothesized that ED volume and increased patient complexity are associated with lower quality of care. They decided to study ED volume instead of crowding because of the multiple definitions of crowding and the lack of agreed upon standard of ED crowding. Demographics, disposition, descriptors of ED visit, age, sex, self-determined race and ethnicity, mode of transport, triage acuity, level of care to which the patient was admitted were collected from an ED maintained administrative database. Date and time of antibiotic administration were abstracted from the ED chart using a structured form. Two abstractors, blinded from ED volume data, performed data abstraction. ED database permits calculation of the hourly volume of the ED on any day and determines the total number of patients as well as the number of patients who were ultimately admitted to the hospital. LWBS patients were included in total volume numbers because they create workload.

Multivariate logistic regression was used to determine the association of total ED volume with antibiotic delivery within 4 hours, controlling for pneumonia patient demographic and clinical characteristics. Analysis was repeated using the number of patients present who were ultimately admitted to the hospital and the number of patients who were discharged. Predictor variables were selected a priori according to how these factors might affect how quickly a patient might be treated. Patients with missing predictor data were excluded from the analysis. LOS was not included as a predictor. The authors checked for influential
observations by examining the impact of deleting the most influential observation on the estimated volume effects. They also compared early data to later data to assess possible influence of staff education campaign and differences in triage acuity related to volume.

Logistic regression provides limited results and does not show trends in the amount of time between ED arrival and antibiotic administration as volume increases. Community–acquired pneumonia was one of the initial areas identified by JCAHO as a hospital core measure for quality of care. Although a 4-hour antibiotic target has been set for pneumonia patients, as with other quality benchmarks, the impact of patient volume on this target has not been studied. Demonstrating a relationship between volume and quality of care is important in bringing resources to bear on solving the crowding issue, as well as improving the ability to meet quality benchmarks.

*Delay in pain management.* A search of PubMed revealed four studies that examined the relationship between ED crowding and pain management (Chen, et al., 2008; Hwang, et al., 2008; Hwang, Richardson, Sonuyi, & Morrison, 2006; Pines & Hollander, 2008). These studies all found that episodes of ED crowding are associated with poor pain management.

Hwang, Richardson, Livote, Harris, Spencer and Morrison (2008) performed a retrospective observational study of 1,068 adult ED patients warranting pain care. The outcomes for this study were (a) documentation of pain assessment, (b) medications ordered, and (c) times of activities. The authors used bivariate analysis using chi-square, t-test, Spearman’s correlation
coefficient, and linear and logistic regression to evaluate ED crowding factors against pain care received. The predictor variables of ED census, number of boarders and boarding burden (number of boarders divided by ED census) were dichotomized to represent high and low values. Although no difference was noted in the documentation of pain assessment or pain follow-up by physicians during high census compared to low census or during periods of high or low boarders, there were direct correlations between ED census and increased time to pain assessment ($r= 0.22$, $p< 0.0001$), as well as time to administration of pain medications ($r= 0.25$, $p< 0.0001$). The predictors of the quality of pain care were dichotomized in this study. Therefore, the strength of the study was minimized. This study only looked at physicians and not nurses, who administer the pain medications, repeatedly assess patients’ pain levels and inform the physician of any changes in the patients’ conditions. In order to comprehend the true effect that ED crowding has on patient care, different types of care providers needs to be assessed.

*Increased mortality.* Nine studies were located that examined the association between ED crowding and increased mortality (Diercks, et al., 2007; Fatovich, 2005; Gilligan, et al., 2008; Hollander, Sites, Pollack, & Shofer, 2004; Miro, et al., 1999; Richardson, 2006; Shenoi, et al., 2009; Sprivulis, Da Silva, Jacobs, Frazer, & Jelinek, 2006; Viccellio, Santora, Singer, Thode, & Henry, 2009). Although ED crowding was measured differently in each study, the majority of these studies found that correlations exist between increased mortality and ED crowding.
Richardson (2006) performed a retrospective stratified cohort study that compared the mortality rate of all patients that entered an Australian ED during shifts classified as "overcrowded" and an equivalent number during "not overcrowded" shifts. During the 736 shifts from both categories, 144 deaths occurred in the overcrowded cohort and 101 deaths occurred in the not overcrowded cohort over the 48-week period (0.42% and 0.31% respectively; p=0.025) with a relative risk for 10-day mortality of 1.34 (95% CI = 1.04 – 1.72). Although the author reports that patients present during overcrowded shifts received inferior care in terms of standard performance (starting appropriate treatment within triage, LWBS rate, boarded in the ED), only descriptive data was provided and no statistical analysis could be located within the article to verify this claim. Additionally, Richardson (2006) used 75% occupancy as the definition of ED crowding. The author did explain that the definition of overcrowding chosen was "necessarily weak to obtain similar cohorts". Because of this decision, the possibility that a more acutely ill population of patients contributed to both overcrowded conditions and increased mortality rates may be an explanation for the significant results. A more comprehensive definition of ED crowding may have provided stronger correlations between crowding and mortality rates. Another limitation of this study is the use of logistic regression to analyze the results. As previously discussed, the dichotomization of crowding levels does not allow for the analysis of how mortality rates would differ between a crowded ED and an overcrowded ED.
Sprivulis, Da Silva, Jacobs, Frazer and Jelinek (2006) examined the effect of crowding on mortality of 62,495 adult ED patients using a retrospective design at 3 Australian EDs over 3 years. The authors used ED occupancy as an indicator of crowding and looked at deaths on Days 2, 7 and 30 after ED admission. The authors developed the Overcrowding Hazard Scale to test the combined effects of hospital and ED occupancy. Logistic regression was used to assess the differences in demographics and clinical characteristics of patients who died by Day 30 and showed that they had longer ED LOS (risk ratio per hour of ED stay, 1.1; 95% CI, 1.1-1.1; p< 0.001) and longer physician waiting times (risk ratio per hour of ED wait, 1.2; 95% CI 1.1-1.3; p=0.01). Using a Cox’s regression, a linear relationship was identified between the Overcrowding Hazard Scale and increased mortality rates on Day 7 (r=0.98; 95 CI, 0.79-1.00). However, no report was provided on the validity and reliability of this instrument. Therefore, the true relationship between ED crowding and mortality cannot clearly be established using this metric.

A retrospective cross-sectional study performed by Shenoi, Ma, Jones, Frost, Seo, and Begley (2008) used the occurrence of ambulance diversion as a proxy for the presence of ED crowding and assessed the prevalence of ambulance diversion and its association with mortality among pediatric hospitals and their patients. The authors reviewed 63,780 total admissions and found that 4,095 (6.4%) children were admitted during periods of ambulance diversion. Bivariate analysis showed that the occurrence of ambulance diversion was protective for mortality (OR= 0.51; 95% CI=0.34 to 0.77). However, this study
demonstrates only a limited effect of crowding because the occurrence of ambulance diversion restricted the degree to which crowding occurred during these times.

Similarly, a retrospective study performed by Fatovich (2005) examining the mortality rate of patients in an Australian ED during times of ambulance diversion showed a statistically significant reduction in patient mortality during periods of ambulance diversion. The results of this study may indicate that ambulance diversion diminishes the influx of patients into the ED. By decreasing the number of patients entering the ED, the staff can meet the needs of the patients already present in the ED during this time. The author fails to report the mortality rates of the patients in the ambulances during diversion periods.

The results of these studies are mixed. When ambulance diversion is used as an indicator of ED crowding, the mortality rates of patients already in the ED during these times decrease. However, the studies performed by Richardson (2006) and Sprivilis, Da Silva, Jacobs, Frazer and Jelinek (2006) demonstrate that when ED crowding is measured using alternative methods there is a correlation between mortality and ED crowding. Because of the mixed results of these studies, future research needs to use valid and reliable measure of crowding. Additionally, the use of continuous variables as outcome measures would provide valuable information as to the impact of the full range of multiple levels of ED crowding.
Vital Signs

Vital signs are simple measurements of physiological parameters that represent a set of objective data used to determine general parameters of a patient’s health and viability. These values influence the doctors’ and nurses’ interpretation of a patient’s overall condition and affect the course of treatment for each patient individually. Historically, vital signs have been considered an integral part of the nursing assessment and often used as a decision-making tool (Gilboy, Travers & Wuerz, 2000).

A search of PubMed revealed 322 articles focusing on vital signs. Once the editorials, clinical practice updates, systematic reviews and non-English articles were excluded, 102 articles remained. Articles that examined the effect of specific medications on vital signs or the comparison on various methods of measuring vital signs based on cost or convenience were excluded, leaving 64 articles in the search. Of the remaining articles, 19 examined the importance of vital signs while only 6 addressed the frequency of monitoring vitals.

Importance of identifying abnormal vital signs. The importance of properly assessing vital signs is well documented. Although recent studies have demonstrated that normal vital signs occur with certain life-threatening conditions such as post injury hemorrhage, community-acquired pneumonia, or deep venous thrombosis (Luna, Eddy, & Copass, 1989: Mariani, Saeed, Potti, Hebert, Sholes, Lewis, et al., 2006; Potti, Panwalkar, Hebert, Sholes, Lewis & Hanley, 2003), numerous studies have provided results that have validated the predictive power of the presence of abnormal vital signs and the clinical importance of
properly monitoring and recording vital signs. Correlations have been found between the identification of abnormal vital signs and the future occurrence of renal insufficiency, shock and stroke (Birkhahn, Gaeta, Van Deusen & Tloczkowski, 2003; Tierney, Brunt, Kesterson, Zhou, L’Italie, & Lapuerta, 2004) as well as increased mortality (Voskresensky, Rivera-Tyler, Dossett, Riordan, & Cotton, 2009). Additionally, several studies have identified relationships between abnormal vital signs and patient deterioration and the need for life-saving interventions (Goldhill, White, & Sumner, 1999; Holcomb, Salinas, McManus, Miller, Cooke & Convertino, 2005; Subbe, Davies, Williams, Ruterfored, & Gemmell, 2003; Tarassenko, Hann & Young, 2007).

Goldhill, White, and Sumner (1999) prospectively examined the charts of 76 patients who were transferred to the intensive care unit from other units within the hospital over a 13-month period. The sample included charts of patients that had been in the hospital for longer than 24 hours. The physiological values and procedure in the 24 hours prior to the transfer were reviewed. The researchers recorded the highest and the lowest documented values for temperature, mean arterial pressure, heart rate, respiratory rate, Glasgow Coma Score, oxygen saturation, arterial blood gas results, urine output, plasma sodium, potassium and creatinine, hemoglobin and white blood cell count. Physiological values were taken from the nursing observation charts, the nursing and medical histories, and the laboratory results charts and then quantified using the APACHE II. Interventions such as continuous positive airway pressure, oxygen administration, central venous access and monitoring, oxygen saturation
monitoring and cardiopulmonary resuscitation were also recorded. Chi-squared and Student’s t-test were used to analyze the data and was used only when an inspection of the data suggested a difference may be present. When the authors compared patients who did and did not receive CPR by analyzing the worst physiological values obtained from the APACHE II score the values for heart rate \( (p= 0.095) \), respiratory rate \( (p= 0.052) \) and pH \( (p= 0.087) \) were all significant. Unfortunately, the authors did not report the values of the Chi-square or t-test results obtained from their analysis.

Although the APACHE II is a commonly used tool, the large amount of data needed may make it difficult to obtain an accurate score and limit the researchers’ ability to obtain multiple results. However, they did report that between 81% and 89% of admissions had initial values recorded for temperature, blood pressure, heart rate and respiratory rate with multiple vital sign recordings available more than 56% of the time.

Holcomb, Salinas, McManus, Miller, Cooke and Convertino (2005) performed an analysis that examined how reliable manual vital signs were in predicting the need for life-saving interventions in trauma patients in the United Kingdom. Their retrospective study looked at the records of 381 pre-hospital trauma patients and divided them into 3 groups: (a) vital signs obtained manually, (b) vital signs obtained manually plus the eye component of the Glasgow Coma Scale and pulse oximetry, and (c) vital signs obtained manually, the eye component of the Glasgow Coma Scale, pulse oximetry plus a fully automated noninvasive blood pressure, heart rate, respiratory rate and end-tidal carbon
dioxide measurement. The researchers used multivariate logistic regression to analyze the results and determine the best predictors of the need for life-saving interventions. The results of the study confirmed that systolic blood pressure (OR= 0.97; 95% CI=0.96 to 0.98), diastolic blood pressure (OR= 0.97; 95% CI=0.95 to 0.98), oxygen saturation (OR= 0.95; 95% CI=0.93 to 0.97), and the presence of radial pulse (OR= 73.12; 95% CI=4.3 to 1242) were significant in predicting the need for life-saving interventions. Additionally, an examination of the ROC curve for the 3 groups revealed that the addition of all automated vital signs measured by the monitor (Group 3’s ROC of 0.975) did not statistically improve the ROC values from the previous group (Group 1’s ROC of 0.969 and Group 2’s ROC of 0.97). However, the addition of a blood pressure device increased the overall predictive power from 81% to 85%. Although the primary purpose of this study was to compare the reliability of manual versus semi-automated versus automated measurement of vital signs, the results of this study demonstrate how abnormal vital signs can be used to predict the need for life-saving interventions.

Cei, Bartolomei, and Mumoli (2009) prospectively examined the predictability of in-hospital mortality and morbidity of elderly medical patients by admission vital signs. Upon admission to the unit, systolic blood pressure, heart rate, respiratory rate, temperature and level of consciousness were measured. From these values a Modified Early Warning Score (MEWS) was calculated. Statistical analysis included two-tailed Student t-test, Chi-square test for dichotomous variables and logistic regression for the main study outcomes of
mortality and transfer to a higher level of care. MEWS values on admission ranged from zero (all physiological measures within acceptable range) to 10 (severely abnormal values of some physiological measures). When compared with patients scoring zero on the MEWS, patients with a (a) MEWS of 1 had the risk of death increase incrementally (OR= 2.92; 95% CI= 1.37 to 6.23) as did the combined risk of death or transfer (OR= 1.84; 95% CI= 1.02 to 3.31), (b) MEWS of 2 had the risk of death (OR= 5.59; 95% CI= 2.65 to 11.81) and the combined risk of death or transfer (OR= 3.12; 95% CI= 1.70 to 5.71), (c) MEWS of 3 had the risk of death (OR= 9.86; 95% CI= 4.49 to 21.65) and the combined risk of death or transfer (OR= 5.37; 95% CI= 2.77 to 10.36), (d) MEWS of 4 had the risk of death (OR= 15.81; 95% CI= 6.70 to 37.35) and the combined risk of death or transfer (OR= 8.40; 95% CI= 3.97 to 17.7), (e) MEWS of 5 or greater had the risk of death (OR= 22.59; 95% CI= 10.45 to 49.16) and the combined risk of death or transfer (OR= 11.38; 95% CI= 5.84 to 22.19). Additionally, a patient with a MEWS of 0 on admission had a very low risk to reach the end points of death or transfer (OR= 0.14; 95% CI= 0.08 to 0.24). The results of this study mirror the results of the previously discussed studies and once again emphasize how abnormal vital signs provide clues to impending deteriorations in patients. The authors report that a limitation of their study is that the most unstable patients were stabilized in the ED prior to their arrival on the unit. In the proposed study, the MEWS will be calculated for emergency patients and may provide important evidence to investigate the use of the MEWS, or other composite vital sign measures, within emergency departments within the United States.
Frequency of vital signs. There is limited information regarding the optimal frequency with which vital signs should be monitored. The majority of the literature addressing the frequency of vital sign monitoring is focused on inpatients and is inconsistent in nature.

Zeitz and McCutcheon (2006) conducted a retrospective review of 144 patient medical records to determine if the frequent collection of routine postoperative vital signs had an impact on the detection of patient complications in one Australian hospital. Alterations in vital signs outside normal parameters, demographic information, and incidence of complications were measured using an audit tool. When a complication was detected, the chart documentation was reviewed to identify what changes occurred in the patient and the processes that were used to detect the change. Pearson correlation and Student’s t-test were used to analyze the data. Increased pulse rate had a weak correlation with the incidence of clinical events (r=0.31, p<0.05) and nausea (r= 0.49, p<0.05), while a lowered heart rate strongly correlated with vomiting (r= 0.63, p<0.05). Vomiting correlated moderately with both lowered temperature (r= 0.63, p<0.05) and increased temperature (r= 0.44, p<0.05). A weak correlation was also identified between nausea and lowered temperature (r= 0.40, p<0.05). Unfortunately, the authors did not report if the nurse adhering to the policy of the frequency with which postoperative vital signs are observed had an impact on the preemptive treatment of clinical events or complications experienced by the patients.

Mariani, Saeed, Potti, Herbert, Sholes, et al. (2006) evaluated the benefits from routine (every 4 to 6 hours vs. every 8 to 12 hours) vital signs, including
temperature, blood pressure, heart rate and respiratory rate, on survival rates, discharge location, and transfers to the intensive care unit in 147 community-acquired pneumonia patients admitted to the hospital between November 2000 and September 2001. Multiple logistic regression was used to analyze the results. Fifty-six (39%) of the patients had vital signs recorded less often than every 6 hours while 87 (60.8%) had vital signs more often than every 6 hours. The authors reported that frequent vital sign evaluation did not result in a significant difference in survival or number of transfers to the intensive care unit, length of stay (SD =3.5, p= 0.14) after adjusting for demographics and comorbid illnesses in the patients. Unfortunately, little statistical proof was provided by the authors to support their claims. Odds ratios and confidence intervals were not provided. Additionally, the authors did not specify if the protocols for the frequency of collecting vital signs was followed or if interventions were performed when abnormal vital signs were identified.

Only one study could be located that examined the factors that affect the frequency with which vital signs are recorded in the ED. Armstrong, Walthall, Clancy, Mullee and Simpson (2008) performed a retrospective review of ED clinical records in the United Kingdom to explore factors that influence the recording of vital signs within the first 15 minutes a patient is in the ED and again within 60 minutes of arrival. The researchers collected data on staffing levels, triage category and the number of patients in the ED and used logistic regression to determine the effect these variables had on the proportion of patients with all vital signs recorded within the 2 time periods. Of the 387 charts reviewed, only
233 (58%) and 29 (7%) had a complete set of vital signs (temperature, heart rate, respiratory rate, blood pressure and oxygen saturation) collected within 15 minutes and 60 minutes, respectively. A significant relationship was identified between lower, or less acute, triage categories and a failure to record respiratory rate (OR = 0.20; 95% CI= 0.07 to 0.55), oxygen saturation (OR = 0.22; 95% CI= 0.08 to 0.65), heart rate (OR = 0.19; 95% CI= 0.07 to 0.58), and blood pressure (OR = 0.18; 95% CI= 0.06 to 0.54). Because the audit only included ED clinical records and did not examine the final charts that accompany admitted patients, vital signs that were recorded only on the patients’ charts may have been missed making the results of this study lower than the actual value. As with several of the other studies, the location of this study limits its generalizability to the United States and other countries due to the differing structures and processes used in the different health care systems.

Conclusion

Research demonstrates that many factors consistently contribute to ED crowding. Some of these factors include increased patient volume, decreased nursing staff, decreased inpatient beds, increased acuity of patients entering the ED, and increased number of patients boarded in the ED (Magid, Asplin, & Wears, 2004). Although the causes of ED crowding are well documented, the effect that crowding has on patient outcomes has not been well documented (Asplin, et al, 2003) and the effect on quality indicators in nursing care is absent. In order to address the issue of ED crowding completely, researchers must examine the consequences as well as its causes.
Multiple studies have examined the relationship between vital signs and adverse patient outcomes. In the literature search for this study, no evidence could be located to support an optimal frequency with which vital signs should be monitored (Evans, Hodgkinson & Berry, 2001; Mariani, Saeed, Potti, Hebert, Sholes, Lewis, et al., 2006; Zeitz & McCutcheon, 2006). With the exception of trauma patients, few studies examine vital signs of general emergency department patients. Likewise, the frequency of vital sign monitoring, well documented in post-operative patients, is rarely addressed in the emergency department research. By neglecting these areas of research, ED patients may not be receiving a sufficient level of quality of care.

Abnormal and significant changes in vital signs can indicate a need to rescue the patient from a potentially life-threatening condition. During periods of ED crowding, it is possible that clinically important vital signs are not recognized, do not receive attention, or are not communicated in a timely fashion. This study differed from previous studies of outcomes in the ED because monitoring and communicating vital signs are a common nursing intervention and, in the ED, independently performed. This study may help to guide future nursing research to determine interventions, such as changes in protocol or the creation of jobs using task specific personnel, to help alleviate or prevent adverse patient outcomes during ED crowding.
Table 2-1 Studies that examined the association between ED crowding and adverse outcomes

<table>
<thead>
<tr>
<th>Focus</th>
<th>Author/Year</th>
<th>Sample</th>
<th>Design/Purpose</th>
<th>Outcome Variable</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antibiotic Delays</td>
<td>Fee, Weber, Maak, Bacchetti, 2007</td>
<td>N=405 adult pts</td>
<td>Cross-sectional. Determine if ED volume in increased pt complexity is associated with lower QOC</td>
<td>time to abx</td>
<td>Abx within 4 hrs was less likely with a greater number of pts (OR 0.96/additional pt)</td>
</tr>
<tr>
<td>Antibiotic Delays</td>
<td>Pines, Localio, Hollander, Baxt, Lee, Phillips &amp; Metlay, 2007</td>
<td>N= 694 adult pts from 1 ED</td>
<td>Descriptive. Determine the impact of ED crowding on delays in antibiotic administration for CAP pts</td>
<td>Time to abx</td>
<td>44% received abx within 4 hrs. 92% received abx in ED. Increasing crowding associated with delayed/no abx. When WR and LOS for admits were low, delays were 31%. When higher, 72%</td>
</tr>
<tr>
<td>Antibiotic Delays &amp; PCI</td>
<td>Pines, Hollander, Localio &amp; Metlay, 2006</td>
<td>24 hospitals</td>
<td>Descriptive. Assess the institutional-level association between measures of ED crowding and process measures for pneumonia and AMI</td>
<td>Time to abx Time to PCI ED LOS was inversely associated with probability of receiving antibiotics for pneumonia within 24 hrs (Spearman p= -0.44, p&lt;.05)</td>
<td></td>
</tr>
</tbody>
</table>

Abx= antibiotics, AMI= acute myocardial infarction, CAP= community acquired pneumonia, ED=emergency department, LOS= length of stay, PCI= percutaneous coronary intervention, pt(s)=patient(s), OR=odds ratio, QOC= quality of care, WR= waiting room
<table>
<thead>
<tr>
<th>Focus</th>
<th>Author/Year</th>
<th>Sample</th>
<th>Design/Purpose</th>
<th>Outcome Variable</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Stay</td>
<td>Bayley, Schwartz, Shofer, Weiner, Sites, Traber &amp; Hollander, 2005</td>
<td>N=817 CP pts from 1 ED</td>
<td>Prospective cohort. Determine additional cost of an extended ED LOS for CP pts awaiting telemetry beds</td>
<td>Cost LOS</td>
<td>ED LOS was not associated with total hospital LOS but annual opportunity costs for the hospital was $168,300</td>
</tr>
<tr>
<td>Length of Stay</td>
<td>Krochmal &amp; Riley, 1994</td>
<td>N=26,020 ED pts at 1 hospital over 3 years</td>
<td>Descriptive Determine the association between ED crowding and healthcare costs</td>
<td>Cost LOS</td>
<td>ED LOS for admission &gt;24 hrs was associated with a 10% increase in hospital LOS</td>
</tr>
</tbody>
</table>

CP= chest pain, ED= emergency department, LOS=length of stay
<table>
<thead>
<tr>
<th>Focus</th>
<th>Author/Year</th>
<th>Sample</th>
<th>Design/Purpose</th>
<th>Outcome Variable</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>Chalfin, Trzeciak, Likourezos, Baumann, &amp; Dellinger, 2007</td>
<td>120 hospitals ICUs from the Project IMPACT database</td>
<td>Cross-sectional. Determine the association between ED boarding and outcomes for critically ill pts</td>
<td>Hospital survival LOS</td>
<td>Mortality of pts transferred to ICU &gt;6hrs was 17.4% vs. 12.9% for pts transferred &lt;6hrs (OR 0.71; 95% CI= 0.56 to 0.89)</td>
</tr>
<tr>
<td>Mortality</td>
<td>Fatovich, 2005</td>
<td>N= 51,885 charts of ED pts from 1 hospital during 1 year</td>
<td>Determine if ED pts have a higher eventual mortality rate is present during periods of ambulance diversion</td>
<td>Death in ED or IP</td>
<td>28% reduction in pt mortality for pts during periods of ambulance diversion. (OR 1.13; 95% CI = 1.13-1.46)</td>
</tr>
<tr>
<td>Mortality</td>
<td>Miro, Antonio, Jimenez, DE Dios, Sanchez, Borras, &amp; Milla, 1999</td>
<td>N= 81,301 from 1 urban university hospital over 2 years</td>
<td>Prospective Assess the influence of crowding on health care quality provided by EDs</td>
<td>Revisits Mortality</td>
<td>Weekly visit volume and ED mortality rate correlated (p&lt;.05)</td>
</tr>
<tr>
<td>Mortality</td>
<td>Richardson, 2006</td>
<td>N=66,608 pts from 1 Australian hospital</td>
<td>Retrospective stratified cohort. Quantify relationship between ED crowding and 10-day pt mortality</td>
<td>In-hospital death</td>
<td>Risk of mortality at 10 days was 1.34 (95% CI=1.04 to 1.72)</td>
</tr>
<tr>
<td>Mortality</td>
<td>Shenoi, Long, Jones, Frost, Seo, &amp; Begley, 2008</td>
<td>N=4,095 ped pts admitted to ED during ambulance diversion</td>
<td>Descriptive. Determine the prevalence of ED ambulance diversion among Houston pediatric hospitals and its association with mortality of ped pts</td>
<td>ED or IP Mortality</td>
<td>Fewer severely ill pts admitted during diversion (OR=0.72 95% CI = 0.66-0.78) Diversion did not show any association with mortality</td>
</tr>
<tr>
<td>Mortality</td>
<td>Sprivilis, Da Silva, Jacobs, Frazer &amp; Jeinek, 2006</td>
<td>N=62,495 ED admissions at 3 hospitals over 3 years</td>
<td>Descriptive. Examine relationship between hospital &amp; ED occupancy &amp; mortality after ED admission</td>
<td>Death on days 2,7 and 30</td>
<td>Hazard ratios for mortality at 2, 7, and 30 days were 1.3, 1.3 and 1.2 for pts admitted during periods of greater ED and hospital occupancy</td>
</tr>
<tr>
<td>Mortality</td>
<td>Viccellio, Santora, Singer, Thode, &amp; Henry, 2009</td>
<td>N= 55,020 admitted pts at a suburban, academic hospital over 4 years</td>
<td>Retrospective cohort. Determine if the transfer of admitted pts from Ed to IP hallways is feasible and not create pt harm</td>
<td>Hospital mortality and ICU transfers</td>
<td>In hospital mortality rates were higher among pts admitted to standard beds (2.6%; 95% CI 2.5% to 3.7%) than among pts admitted to hallway beds (1.1%; 95% CI 0.7% to 1.7%) ICU transfers were also higher in standard bed admissions (6.7%; 95% CI 6.5% to 6.9% vs. 2.5%; 95% CI 1.9% to 3.3%)</td>
</tr>
</tbody>
</table>

CI= confidence interval, ED= emergency department, ICU= intensive care unit, IP= inpatient, LOS= length of stay, OR= odds ratio, ped= pediatrician, pt(s)= patient(s)
<table>
<thead>
<tr>
<th>Focus</th>
<th>Author/Year</th>
<th>Sample</th>
<th>Design/Purpose</th>
<th>Outcome Variable</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>Hwang, Richardson, Sonuyi, &amp; Morrison, 2006</td>
<td>N= 158 Charts of older pts (age&gt;50) with hip fx in 1 ED</td>
<td>Retrospective Evaluate the effect of ED crowding on assessment and treatment of pain in older adults</td>
<td>Documented pain assessment Time to pain assessment Time to pain treatment</td>
<td>Occupancy &gt;120% was associated with lower likelihood of pain score (OR =0.46; 95% CI= 0.21 to 0.98). No difference in giving of med (OR =2.02; 95% CI= 0.89 to 4.62)</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>Hwang, Richardson, Livote, Harris, Spencer &amp; Morrison, 2008</td>
<td>N= 1,068 adult pts presenting with c/o pain at 1 hospital</td>
<td>Retrospective observational. Evaluate the association of ED crowding factors with quality of pain care</td>
<td>Documentation of clinician pain assessment, med ordered and time of activities</td>
<td>Fewer pts received pain meds during periods of high census. A direct correlation with total ED census and time to pain assessment (r=0.33, p&lt;0.0001) time to pain med ordering (r=0.22 p&lt;0.0001) &amp; time to pain med (r=0.25 p&lt;0.0001)</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>Pines &amp; Hollander, 2008</td>
<td>N= 13,758 adult pts with severe pain</td>
<td>Descriptive. Study the impact of ED crowding on delays in treatment and non-treatment for pts with severe pain</td>
<td>Pain meds received in ED Delay from triage to 1st pain med Delay from room placement to 1st pain med</td>
<td>Nontx was assoc with 1) WR #s (OR 1.03 for each add waiting pt.) 2) occupancy rate (OR 1.01 or each 10% increase) and predicted delays in pain meds from triage (OR 1.05) &amp; delay in pain meds (OR 1.02)</td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI= confidence interval, c/o= complaint of, ED= emergency department, fx= fracture, med(s) = medication(s), OR= odds ratio, pt(s) = patient(s)
<table>
<thead>
<tr>
<th>Focus</th>
<th>Author/Year</th>
<th>Sample</th>
<th>Design/Purpose</th>
<th>Outcome Variable</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfaction</td>
<td>McMullan &amp; Vesper, 2004</td>
<td>N= 12 hour shifts in 1 year in small, low-volume academic ED</td>
<td>Retrospective ED census review. Determine how ED volume and acuity influence LWBS rate</td>
<td>LWBS rate</td>
<td>629/18,664 pts LWBS. Increased ED volumes were associated with more LWBS (p&lt;0.001). Increasing LWBS were associated w/ higher acuity (p&lt;0.05)</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Pines, Garson, Bax, Rhodes, Shofer &amp; Hollander, 2007</td>
<td>N= 644 pts, 703 MDs, 716 RNs</td>
<td>Cross-sectional survey. Measure the association between ED crowding and pt and provider perceptions about pt care compromise</td>
<td>Agreement on a 5-itme scale assessing whether ED crowding compromised care</td>
<td>For pts= care compromised by WR time (OR 1.05 for 10 min; 95% CI=1.02-1.09), being in a hallway (OR, 2.02; 95% CI =1.12-3.68) For RNs= predicted by WR time (OR 1.05 for each 10 min; 95% CI = 1.01-1.08), # of pts in WR (OR, 1.05; 95% CI =1.02-1.07) &amp; # of pts waiting for IP beds (OR, 1.08; 95% CI =1.03-1.12) For MDs= pt/RN ratio (OR,1.39 for each 1 unit increase; 95% CI =1.09-1.20) &amp; # of pts waiting for IP beds (OR, 1.14; 95% CI =1.10-1.75)</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Pines, Iyer, Disbot, Hollander, Shofer &amp; Dafner, 2008</td>
<td>N=1,469 pt surveys over a 2 yr period at 1 hospital</td>
<td>Retrospective cohort. Study the association between factors related to ED crowding and pt satisfaction</td>
<td>Pt satisfaction for both ED care and overall hospital satisfaction</td>
<td>ED hallway= less likely recommend ED &amp; overall sat (p&lt;.05). long ED boarding times &amp; tx times =lower sat (p&lt;.05). ED crowding &amp; wait times predicted ED sat (p&lt;.05) but not hosp sat.</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Sun, Adams, Orav, Rucker, Brennan, &amp; Burstin, 2000</td>
<td>N= 2,899 surveys from 5 urban EDs.</td>
<td>Survey. ID ED process of care measures associated w/ sat &amp; likely to return.</td>
<td>Patient satisfaction</td>
<td>Greater dissat when patients not informed about waits (OR =.48; 95% CI =.39-.57)</td>
</tr>
</tbody>
</table>

Abx= antibiotics, CAP= Community acquired pneumonia, CP=chest pain, ED= emergency department, fx= fracture, ICU =intensive care unit, IP= inpatient, LOS= length of stay, Nontx= non-treatment, pt(s) = patient(s), PCI= Percutaneous intervention, QOC= Quality of Care, sat= satisfaction
<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Sample</th>
<th>Design/Purpose</th>
<th>Outcome Variables</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baldursdottir and Jonsdottir, 2002</td>
<td>Convenience sample of 300 ED patients response rate = 60.7%, Iceland, d/c from ED</td>
<td>Descriptive</td>
<td>Identify which nurse caring behaviors are perceived by patients in an ED as important indicators of caring</td>
<td>clinical competence = the most important nurse caring behaviors</td>
</tr>
<tr>
<td>Chen, Shofer, Dean, Hollander, Bax, Robey, Sease &amp; Mills, 2008</td>
<td>N=981 ED adult pts with acute abd pain</td>
<td>Prospective cohort.</td>
<td>Assess whether gender disparity exists in the administration of analgesia for acute abd pain</td>
<td>Women were less likely to receive any analgesia (7% difference, 95% CI = 1.1% - 13.6%). Women waited longer to receive analgesia (median time 65 min vs. 49 min, 95% CI =3.5-33 min)</td>
</tr>
<tr>
<td>Cioffi, Salter, Wilkes, Vonu-Boriceanu, &amp; Scott, 2006</td>
<td>18 emergency room RNs &amp; MDs in 3 focus groups from Sydney, Australia</td>
<td>Descriptive. (Qual)</td>
<td>Describe clinicians’ response to abnormal vital signs in ED</td>
<td>Delays result from increased workload, inadequate documentation, stress, poor communication, lack of support, &amp;inexperience</td>
</tr>
<tr>
<td>Diercks, Roe, Chen, Peacock, Kirk, Pollack, Gibler, Smith, Ohman &amp; Peterson, 2007</td>
<td>N=42, 780 non-STEMI pts</td>
<td>Secondary Analysis.</td>
<td>Evaluate the association of ED LOS with use of recommended therapies for acute tx &amp; clinical outcomes</td>
<td>Pts with long ED stays less often received recommended AMI therapies. Rate of recurrent MIs increased among pts with long ED stays (OR =1.23; 95% CI = 1.01 -1.48)</td>
</tr>
<tr>
<td>Lyneham, Cloughessy, Martin, 2008</td>
<td>N=394 Australian EDs</td>
<td>Descriptive. Survey</td>
<td>Identify current workload of nurses and determine the relationship of experienced to inexperienced clinical staff</td>
<td>RN: pt ratio was 1:15 am, 1:7pm and 1:4 night. 17.1% of pts admitted to hosp (ave). 27 staff members for each manager and 23.3 clinical staff for each educator. Jr staff ranged from 10- 38%</td>
</tr>
<tr>
<td>Vieth &amp; Rhodes, 2006</td>
<td>N=310 adults in ED WR surveyed with 174 participating in follow-up phone call</td>
<td>Descriptive. Evaluate ED access and provider and pt assessment of quality</td>
<td>LWBS rate Opinion of pts in WR, MDs and RNs in Real time</td>
<td>MD &amp; RN had 81% agreement of crowding (k=.54) 47% of 57 shifts at least 1 provider felt that crowding was compromising QOC.</td>
</tr>
</tbody>
</table>

abd= abdominal, AMI= acute myocardial infarction, AVS= Abnormal vital signs, d/c = discharge, ED= Emergency Department, LWBS= left without being seen, MET= medical emergency team, MI= myocardial infarction, QOC= quality of care, tx= treatment, WR= waiting room
Table 2-3. Studies that look at the assessment of vital signs/physiological changes as prediction of adverse outcomes

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Sample</th>
<th>Design/Purpose</th>
<th>Outcome Variables</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong, Walthall, Clancy, Mullee &amp; Simpson, 2008</td>
<td>N=387 charts of adult ED pts in the ‘resuscitation’ or ‘major’ areas of the ED (UK)</td>
<td>Retrospective -Examine factors that may influence the recording of vital signs within the initial 15 minutes and again within 60 minutes of arrival in the ED</td>
<td>Complete set of vital signs recorded</td>
<td>223/387 (58%) had all vitals recorded within 5 minutes and 29/387 (7%) had all vitals repeated at 60 min. Sig relationship between failure to record vitals and lower triage categories (less acute). No evidence that staffing levels or number of attendances predicted the recording of vitals within 15 min of arrival.</td>
</tr>
<tr>
<td>Cei, Bartolomei, &amp; Mumoli, 2009</td>
<td>N= 1107 consecutively admitted patients from November 2005 to June 2006 (Italy)</td>
<td>Prospective. Cohort. Investigate the ability of the MEWS to identify a subset of patients at risk of deterioration, who might benefit from an increased level of attention</td>
<td>In-hospital mortality Transfer to a higher level of care Length of stay (for discharged patients)</td>
<td>Pts with MEWS &lt; or= 4 were d/c after mean of 8.3 days. Alive pts with MEWS of 5 or more were d/c after mean LOS of 9.4 days (p=ns). Pt with MEWS of 0 at admit has very low probability to die or be transferred d/t instability (OR 0.14, 95% CI 0.08-0.24)</td>
</tr>
<tr>
<td>Gardner-Thorpe, Love, Wrightson, Walsh &amp; Keeling, 2006</td>
<td>N=334 consecutive ward patients (UK)</td>
<td>Observational. Prospective. Determine if the MEWS is useful in surgical inpatients to prevent delays in interventions or transfer of critically ill pts.</td>
<td>Transfer to critical care facility</td>
<td>MEWS of 4 or more was 75% sensitive and 83% specific for patients who required transfer</td>
</tr>
<tr>
<td>Goldhill, White &amp; Sumner, 1999</td>
<td>N=76 pts in hospital &gt;24 hrs (UK)</td>
<td>Descriptive. -Describe reasons for ICU admission in hospital inpatients</td>
<td>ICU admission</td>
<td>Problem with Airway, Breathing or Circulation precipitated ICU admit. HR, RR</td>
</tr>
</tbody>
</table>
Identify physiological values likely to be associated with a patient at risk and adequate oxygenation are the most important physiological indicators.

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Sample Description</th>
<th>Methodology</th>
<th>Primary Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holcomb, Salinas, McManus, Miller, Cooke &amp; Convertino, 2005</td>
<td>Descriptive, Retrospective</td>
<td>N=381 prehospital trauma patient records Random sample (USA)</td>
<td>The use of life-saving intervention Manual and semi-automated vital sign measurements have a significant predictive capacity that's only slightly lower than the fully automated group.</td>
<td></td>
</tr>
<tr>
<td>Mariani, Saeed, Potti, Hebert, Sholes, Lewis, Hanley, 2006</td>
<td>Prospective. Cohort.</td>
<td>N=147 inpatient CAP pts (USA)</td>
<td>Survival rate Transfer to ICU Discharge location No significant difference in survival, LOS, or ICU admit between pts with VS q4-6hr vs. 8-12 hrs</td>
<td></td>
</tr>
<tr>
<td>Subbe, Davies, Williams, Rutherford &amp; Gemmell, 2003</td>
<td>Prospective.</td>
<td>N=1695 acute medical pts (UK)</td>
<td>-rate of ICU or HCU admission -cardio-pulmonary arrest -mortality. No statistically significant difference Proportion of pts admitted to ICU did not change, but trend toward earlier admission was observed</td>
<td></td>
</tr>
</tbody>
</table>

CAP= community acquired pneumonia; ED= emergency department; HCU= high dependency unit; HR= heart rate; ICH= Intracranial Hemorrhage; ICU= intensive care unit; pt(s) = patient(s); LOS= length of stay; MEWS= modified early warning score; RR= Respiratory rate; VS= vital signs
Chapter Three

Methods

This chapter outlines the methodology used in this study by providing descriptions of the study’s design, instrumentation of the variables of interest, sampling method and the rationale for the methods and instruments chosen. Additionally, human subjects’ protection, data collection procedures, data management, and data analyses are also outlined.

Research Questions

RQ1. Was there an association between the length of time between vital signs recording and differing degrees of ED crowding?

RQ2. On days when the ED was crowded, what factors influenced the frequency with which emergency nurses monitored patients’ vital signs?

RQ3. What factors influenced the time to the emergency nurse’s initial response when abnormal vital signs were present?

RQ4. What effect did the degree of ED crowding have on the measurement of vital signs for a patient in the ED?

Design

In order to address these research questions, a retrospective, descriptive, correlational research design was used. More specifically, a retrospective chart audit of ED patients was performed to answer the research questions. Although an experimental or quasi-experimental design would have produced stronger evidence by establishing or refuting the causality of relationships, there are limited prior studies addressing the effect of ED crowding on patient outcomes.
(Hulley, Cummings, Browner, Grady & Newman, 2007). Therefore, this non-experimental design was required to identify important variables and determine their inter-relationships prior to performing an experimental design. A retrospective design was chosen because it would provide a large amount of data and Level IV evidence on which additional studies may be built (Lobiondo-Wood & Haber, 2002, p.243). A descriptive study of the variables in this project has potential to determine the need for further investigations of the topic, to assist in the development of hypotheses for future studies and to identify potential future intervention-level projects (Brink & Wood, 1989).

Setting

This study was conducted using charts from the Emergency Department of University Hospitals Case Medical Center (UHCMC) in Cleveland, Ohio. The hospital reports that approximately 50% of all inpatients at UHCMC are admitted through the ED. UHCMC is an academic medical center whose ED has 41 treatment beds. The ED was built to serve 40,000 patients per year, but cares for 73,000 emergency patients annually, making it an ideal setting to perform a study on ED crowding (University Hospitals, 2008).

Sample

The sample included medical records of adults admitted to the ED. The sample also consists of electronic databases that track multiple factors of crowding including registration time, time of ED room assignment, ED census, number of admitted patients in the ED. Registration data and patient chart data were maintained in the medical records department within UHCMC. The
Inclusion/exclusion criteria. The inclusion criteria included all the charts of patients assigned to an ED room or hallway bed during periods of time with different crowding levels. Charts of patients within triage categories four and five were not included in this study. Charts of patients with incomplete baseline/triage vital sign records were excluded. Only charts of patients remaining in the ED for 3 hours or longer were included. Patients that were assigned to ED beds for less than 60 minutes during a crowding period were not included in that period.

Rationale for inclusion/exclusion. Patients classified within triage categories four and five are not always treated within the main ED and may be deferred to the fast track area of the ED during designated hours of operation. Because patients with an incomplete triage vital sign recording would not allow for proper calculation of a baseline composite vital sign score, those charts were excluded. Patients with an ED length of stay less than 3 hours were excluded because they would be less likely to have had vital signs repeated during their ED stay. Patients that were assigned to ED beds for less than 1 hour of a crowding period were excluded because they may not experience the effects of ED crowding.

Sample size. The five studies that were located that examine the association between ED crowding and treatment delays had sample sizes that ranged from 158 to 13,758 (Fee, et al., 2007, Hwang, Richardson, Soluyi & Morrison, 2006; Pines & Hollander, 2008; Senior & Patel, 1998). Hwang et al
(2006), studying a sample of 158 elderly subjects with hip fractures (alpha=.05), reported an odds ratio of .46 of crowding with decreased pain management; the researchers did not report the power or effect size for the study. Another study conducted by Fee et al (2007), examining the relationship between ED crowding and the time to antibiotics in 486 pneumonia patients (alpha = .05), reported an odds ratio of .96. Studies performed by Senior and Patel (1998), Fee et al (2007), Hwang, et al (2006), Pines, et al (2007) used logistical regression and provided odds ratios ranging from .46 to 1.44. None of the studies reported the effect size or power of the studies. The inconsistencies within the previous studies’ odds ratios, and the lack of reported power and effect sizes assumed by the authors, lead this study to anticipate a medium effect size.

Effect size refers to a standardized, objective measure of the magnitude of the effect that the independent variable has on the dependent variable and is based on previous research results (Fields, 2005). When a small effect size is present the independent variable accounts for 1% of the total variance of the dependent variable, while medium and large effect sizes account for 9% and 25% of the total variance, respectively (Cohen, 1969). The larger the effect size, the smaller the sample size needs to be to detect its impact. Conversely, as the effect size decreases, the power of the statistical test decreases. Statistical power is the probability that a test will detect an effect, or yield statistically significant results. The power of a test is calculated by subtracting the probability of a Type II error from 1 (1-β). A type II error is the probability of reporting a false negative result while a Type I error is the probability of reporting a false positive
result. A type II error, β, is usually set at 0.20 because Type I errors, α, are conventionally set at 0.05 and are four times as serious as Type II errors (Cohen, 1988, p.54).

According to Cohen (1992), the medium effect size for a multiple correlation, the most conservative estimate of sample size, is 0.15. By assuming an alpha of .05, a beta of .80 and a medium effect size (f²= 0.15) for a multiple regression with fourteen independent variables, the sample size for this study was calculated to be 135 charts. This sample size was determined by inputting the components of power analysis into the Gpower3.0.10 program (Faul, Erdfelder, Lang, & Buchner, 2007). However, in order to perform structural equation modeling as an analysis method, a minimum sample size of 200 subjects is required (Kline. 2005, p. 15). By maintaining a power of 0.80, the probability of a Type I error of 0.05, and increasing the sample size to 200, the expected observable effect size for this study was decreased to 0.098. This means that this study is more sensitive to the influence of the independent variables and can capture a smaller change that can occur due to the independent variables.

A list of all patients present in the ED during the four pre-selected weeks was obtained from the Electronic Medical Records Department. Crowding levels were calculated for six 4-hour time periods per day using the Emergency Department Work Index (EDWIN) calculation. After the EDWIN score was calculated, all the patients with triage categories of 4 or 5 were removed from the list of potential subjects. The ED is divided into two sections, the main ED and
fast track. Fast track is an area in which a low-acuity (e.g. triage category 4 or 5) patient requiring minimal intervention, such as limb x-rays, receives care followed by discharge to home. Because most fast track patients do not receive significant interventions or repeated vital sign measurements, this population was excluded. Only the charts of patients seen in the main ED were included in this review. Once the crowding level was identified for all 168 time periods, 12 shifts were randomly selected from the list of crowded periods. This process was repeated for the noncrowded shifts and 4 time periods were chosen. The list of ED patients presenting during each of the chosen time periods was divided into crowded and noncrowded groups. From each list, a random sample of patients’ charts was obtained, 165 from the crowded and 60 from the noncrowded list. The 225 charts of the selected sample were requested from Medical Records. Data were manually extracted from the sample charts by the principal investigator (PI). Similar sampling strategies have been used by researchers in previous studies (Fee, et al, 2007; Hwang, et al, 2006). This study did not include patient identifiers as described by the Health Information Portability and Accountability Act rules.

Data Collection /Study Procedures

Procedure

The initial step in identifying eligible charts was to first identify periods of crowding. EDWIN scores were calculated at 4-hour intervals that reflect half of an 8-hour shift (i.e. 7:01am to 11:00am, 11:01am to 3:00pm, 3:01pm to 7:00pm, etc). Four weeks were chosen from which the sample was to be obtained.
(January 11-17, 2009, March 8-14, 2009, June 14-20, 2009, and October 11-17, 2009). These weeks were chose because they represented four distinct times of the year and did not include any major holidays that would affect normal census numbers for that season. This procedure provided a representative snapshot of variations in ED occupancy throughout the year. For each day in the chosen week of 2009, data was gathered from the Electronic Medical Records Department to determine crowding levels for each interval. Intervals with EDWIN scores over 2 were identified as crowded. Once the EDWIN scores were calculated, all subjects that did not meet inclusion criteria were removed (i.e. Triage category of 4 or 5). The subjects present during the crowded periods for each week were separated from those present during the noncrowded periods and assigned a number. From those lists, 55 charts were randomly selected from each season using a random number generator. For each of these periods, 40 charts were selected from the crowded periods and 15 charts from the noncrowded period. Although only 200 charts were to be included in the analysis, 20 additional charts were randomly selected for a total of 225 charts that were then requested from the Medical Records department. The purpose of this oversampling was to compensate for charts that could not be located or had excessive missing data. Data points were obtained from the patient’s ED record and registration form and recorded on a tool designed by the PI (See Appendix 7). The researcher maintained a log to note problems, concerns or issues that developed during data collection and reported them in the Discussion section of this study.
Chart Extraction

Protocol. Charts of patients present in the ED during the pre-selected weeks were obtained from the census sheet secured from the Electronic Health Record log. The list of names was provided to the Medical Records Department at UHCMC. All located charts were reviewed and data were gathered from the emergency record and registration sheet. De-identified data were recorded onto a PI designed data collection sheet. Information available in subsequent admissions or at later times during an admission after the patient was transferred from the ED was not included because this information was unavailable to the emergency personnel making clinical decisions during the patient’s stay within the ED. However, if a patient returned to the ED within 48 hours from the time of discharge, that fact was recorded.

Reliability/validity of health records/chart extraction. Some of the factors that influence the reliability and validity of health record data are clinical competence of the recorder, patient cooperation, setting of care, situational factors and the type of data being recorded (Aaronson & Burman, 1994). The Aaronson and Burman (1994) report that physical assessment findings (i.e. vital signs, heart sounds, and weight) are relatively unambiguous and have higher reliability than measures that require accurate client recall or clinician interviewing competence. These authors recommended: (a) identifying clear definitions for coding schemes and criteria for extracting data, (b) implementing detailed procedures for selecting, obtaining and assigning records, and (c) reviewing the records to be used prior to using these records to ensure that the
desired data are available (Aaronson & Burman, 1994). This researcher reviewed several ED patient charts prior to beginning this study and determined that the desired data were available within the majority of the reviewed charts.

Instrumentation

*ED Crowding*

There are several acceptable measurements of ED crowding. Richardson (2006) measured ED crowding as patient occupancy at, or greater than, the 75th percentile for a given time period. Although this definition is simple to calculate, many researchers believe that it does not capture the multiple facets of ED crowding (ACEP, 2002; Asplin, Magid, Rhodes, Solberg, Lurie, & Camargo, 2003). The National Emergency Department Over-Crowding Study (NEDOCS) is another accepted measure of ED crowding and has been used by many large emergency departments (Weiss, Derlet, Arndahl, Ernst, Richards, Fernandez-Frackelton, et al., 2004). The NEDOCS has been developed as an online calculator that uses an algorithm to assign a crowding score to the ED. However, this tool has several variables that are not in the available database; thus a NEDOCS score could not be calculated. After discussing this study with the developer of the NEDOCS, he recommended the use of the EDWIN because the EDWIN would be a more appropriate instrument for this retrospective study (personal communication, Steven Weiss, March 29, 2009).

*EDWIN.* The EDWIN incorporates important components of the Input/Throughput/Output model such as the number of patients, acuity, numbers of physicians on duty, and bed availability, into a single omnibus index. In one
study, the EDWIN correlated well with nurse and physician assessments of crowding (Bernstein, Verghese, Leung, Lunney & Perez, 2003). In a recent six-ED study, the EDWIN correlated well with ED length of stay for admitted patients, ambulance diversion and LWBS rates, although it was outperformed on the latter two measures by ED occupancy rate (Bernstein, Verghese, Leung, Lunney, & Perez, 2003).

The EDWIN is defined as \( \Sigma (n(i) t(i)) / N(a) (B(T) - B(A) ) \), where \( n(i) \) = number of patients in the ED in triage category \( i \), \( t(i) = \) triage category, \( N(a) = \) number of attending physicians on duty, \( B(T) = \) number of treatment bays, and \( B(A) = \) number of admitted patients in the ED (Bernstein, Verghese, Leung, Lunney, & Perez, 2003). A score of 1.7 or higher is considered crowded. For this study, an EDWIN score of 2 or greater was used to identify periods of crowding.

The EDWIN correlated well with other validated measures of ED crowding, such as the NEDOCS and showed good discrimination for predicting ED crowding with an Area under the Curve (AUC) of 0.81 (95% CI 0.77 to 0.85) (Hoot, Zhou, Jones, & Aronsky, 2007; Weiss, Ernst, & Nick, 2005). This establishes construct validity for these scales as valid measures of ED crowding.

Which scale is used in an ED is dependent upon which set of data is most readily available, with the favored scale being the NEDOCS for prospective studies and the EDWIN for retrospective studies. Nurses and physicians showed good inter-rater agreement of crowding assessment (weighted \( k = 0.61 \), 95% CI= 0.53 to 0.69). Additionally, EDWIN correlated well with staff assessment of ED crowding.
and diversion (Bernstein, Verghese, Leung, Lunney & Perez, 2003; Weiss, Ernst, & Nick, 2006).

**Demographic Variables**

Demographic variables were obtained to describe the characteristics of the sample population and were collected on a tool designed by the principle investigator (PI). These data were used to illustrate the study sample for comparison with other studies. In addition, demographic variables were identified as potential factors that might have influenced the length of time between vital signs. The demographic variables included in this study were: gender (male or female), payment method, (self pay, Medicaid, Medicare, private insurance), age, marital status and ethnicity (Caucasian, African American, Asian, Hispanic or other). Gender and age have both been associated with delayed care in the ED during times of crowding (Chen, et al., 2008; Hwang, Richardson, Sonuyi, & Morrison, 2006).

**Arrival Information**

Information regarding the patient’s arrival was also recorded on a PI designed data collection tool. The mode of arrival (i.e. ambulance, private car, police escort) was recorded as well as the time of the patient’s arrival. The triage and registration times were recorded. The presence of family and the relationship of any family members present were recorded when this information was documented in the chart. These data points were thought to have the potential to influence the delay or facilitation of triage, admission, and treatment. Collecting
these data points would also allow for comparisons with previous and future research.

**Patient Health Status**

Health status was defined as the presenting complaint and the comorbidities present upon admission to the ED. The patient’s presenting complaint was obtained from the triage assessment. A list of pre-existing conditions was obtained from the previous medical history section of the ED chart. The number of over-the-counter (OTC) and prescription medications reportedly taken routinely by the patient was recorded. This information was obtained by the triage nurse, either verbally or in written form, from the patient, family member, or from a previous medical chart when available. Only conditions that were active at the time of the ED visit were included as co-morbidities. For example, a broken femur with no sequellae, that has healed (e.g. more than 12 weeks prior to the ED admission), was not counted as a co-morbidity. One exception to this was a diagnosis of any cancer; this diagnosis even in the remote past was included. Comorbidities were categorized into body systems (cardiovascular, pulmonary, gastrointestinal, renal, reproductive, dermatologic, nervous system and psychological). Cancer, regardless of body system, was a separate category. Any previous illness or active conditions were thought to potentially influence the minutes between vital sign recordings, as well as the interpretation of abnormal values.
**Triage Category**

The triage category recorded in this study was determined using the Emergency Severity Index version 4 (ESI) (see Appendix 1). In 1999 the first version of the ESI was developed in the United States to answer the question, ‘How long can everyone wait?’ It is a standardized five-level triage scale used to facilitate the prioritization of patients based on the urgency of the patients’ conditions and resources required to treat the patient (ahrq.hhs.gov/research/esi/esi2.htm). The ESI version 4 has been most recently revised in 2008.

The ESI has five levels to which patients can be categorized. Level 1 indicates the most urgent category of patients and makes up only 1 to 3% of all emergency patients (Eitel, Travers, Rosenau, Gilboy, & Wuerz, 2003; Wuerz, Milne, Eitel, Travers, Gilboy, 2000; Wuerz, Travers, Gilboy, Eitel, Rosenau, & Yazhari, 2001). Patients in triage level 1 require immediate care because death is imminent (i.e. cardiac arrest, severe respiratory distress, unresponsive critically injured trauma patient, anaphylactic reaction). Patients are classified as level 2 if they are: (a) in a high-risk situation, (b) confused, lethargic or disoriented, or (c) in severe pain or distress. Approximately 20 to 30% of emergency patients are classified as level 2 (Eitel, Travers, Rosenau, Gilboy, & Wuerz, 2003). Once it has been determined that the patient does not belong in level 1 or 2, the amount of resources required to diagnose the patient is assessed. Patients in levels 4 and 5, collectively accounting for 20 to 35% of ED volume, indicate the least urgent categories; patients in these categories require only one or no additional
resources to make a diagnosis (Gilboy, Tanabe & Travers, 2005). Generally, patients categorized into levels 4 and 5 can be placed in urgent care or fast track. Patients in these categories are physically stable and can wait several hours to be seen. Level 3 patients require many different resources and make up approximately 30 to 40% of ED patients. Before a patient is placed into the level 3 category, the triage nurse assesses the patient for vital signs that are outside of age-acceptable parameters. The triage nurse may upgrade a patient from level 3 to level 2 because of abnormal vital signs. Three vital signs are used to sort adult patients: pulse (HR > 104) respiratory rate (>20) peripheral oxygenation (< 92%). This system of triage is endorsed by both the Emergency Nurses Association and the American College of Emergency Physicians. The ESI has been recommended as a valid and reliable triage system (Fernandes, Tanabe, Gilboy, Johnson, McNair, Rosenau, et al., 2005). It is commonly used in EDs in the U.S. and was being used at the study site during the sampling time. The triage category was taken from the ED record. This sample was expected to contain triage levels 1 through 3.

Reliability and validity. Studies have found that the ESI is both valid and reliable. Results of a study of more than 200 triage nurses from seven sites using the ESI to evaluate 40 case studies indicated substantial inter-rater reliability with kappas ranging from 0.70 to 0.80 (Eitel, Travers, Rosenau, Gilboy & Wuerz, 2003). A study of 403 ED patients evaluated the reliability of the ESI and found a kappa of 0.89 (Tanabe, Gimbel, Yarnold, Kyriacou & Adams, 2004). The validity of the ESI has been established through the examination of several thousand
patients. Studies have found consistent, strong correlations of the ESI with hospitalization rates, length of stay and mortality (Eitel, et al., 2003, Tanabe, Gimbel, Yarnold, Kyriacou & Adams, 2004, Wuerz Travers, Gilboy, Eitel, Rosenau & Yazhari, 2001)

**Vital Signs**

*Baseline/Triage.* Six vital signs were gathered from the triage section of the patient’s chart and recorded as baseline values on a PI designed tool. Heart rate was measured in beats per minute (bpm). Respiratory rate was measured in respirations per minute (rpm). Peripheral oxygenation was measured as a percentage. Temperature was measured in degrees Centigrade (C°). Pain was recorded on a scale of 0-10. The systolic blood pressure (SBP) was recorded in millimeters of mercury (mmHg).

*Length of time between vital signs.* Each instance a vital sign was repeated, the time was recorded. Additionally, every time that the measurement was noted in the chart, the time was recorded on the PI designed tool. The time between each recorded vital sign was calculated for the subject’s entire stay. The time for the stay began with the time that the patient was assigned to an ED treatment bed and ended with the documented discharge time. The number of times vital signs were obtained for each subject was counted. And the total length of stay was divided by the number of times vital signs were recorded.

*Abnormal vital signs (MEWS).* Abnormal vital signs were identified using the Modified Early Warning Score (MEWS). The MEWS is a measure that provides a composite score for four physiological measures of vital signs as well
as one observational assessment. The four vital signs used to calculate the MEWS are the systolic blood pressure, heart rate, respiratory rate and body temperature. The observational component is the patient’s level of responsiveness. Each component is assigned a score based on its value at the time of collection (see Table 3). The scores for each component are then summed to provide a total MEWS result. The vital signs were recorded on the PI designed tool for triage, the first repeated vital signs and discharge. MEWS scores were then calculated from the vital signs recordings. Although previous research shows that a total score of 5 or greater is determined to be a critical score, the Institute for Healthcare Improvement (IHI) recognizes a score of 4 as a need for intervention (Subbe, Kruger, Rutherford & Gemmel, 2001).

<table>
<thead>
<tr>
<th>Score</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP (mmHg)</td>
<td>&lt;70</td>
<td>71-80</td>
<td>81-100</td>
<td>101-199</td>
<td>101-110</td>
<td>&gt;200</td>
<td>&gt;130</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>&lt;40</td>
<td>41-50</td>
<td>51-100</td>
<td>9-14</td>
<td>15-20</td>
<td>111-129</td>
<td>&gt;130</td>
</tr>
<tr>
<td>Resp. rate (rpm)</td>
<td>&lt;9</td>
<td>9-14</td>
<td>15-20</td>
<td>35.0-38.4</td>
<td>Alert</td>
<td>React to Voice</td>
<td>React to Pain</td>
</tr>
<tr>
<td>Temp (°C)</td>
<td>Alert</td>
<td>React to Voice</td>
<td>React to Pain</td>
<td>Unresponsive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responsiveness (AVPU)</td>
<td>Alert</td>
<td>React to Voice</td>
<td>React to Pain</td>
<td>Unresponsive</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reliability and Validity of MEWS. Studies performed in the United Kingdom, China, and Australia have found that the MEWS was both a valid and a reliable instrument. Results of a study of 709 medical emergency admissions established the validity of the MEWS by demonstrating that a value of 5 or greater was associated with an increased risk of death (OR 5.4, 95% CI 2.8-10.7) and ICU admission (OR 10.9, 95% CI 2.2-55.6). A study performed in China examined the prediction value of the MEWS by evaluating 790 ICU patients. Sensitivity was 89.66% and specificity was 86.21% in predicting death in patients.
with a MEWS score of 5 or greater (Li & Ye, 2008). Subbe, Gao and Harrison (2007) performed a study assessing the inter-rater and intra-rater reliability of the MEWS on medical and surgical wards by four raters. The inter-rater study consisted of 424 sets of measures collected by a senior doctor, a junior doctor, a registered nurse and a student nurse for 114 patients. There was no significant difference among the raters in mean score for the MEWS (p=0.40) and a moderate level of agreement of MEWS total scores (kappa= 0.56, 95% CI 0.42, 0.68). In the intra-rater study, 180 sets of observations from 45 patients were included and resulted in correlation coefficient of 0.98 (0.94-1.00). Additionally, studies have found consistent, strong correlations of the MEWS regarding length of stay, morbidity in elderly medical patients, and mortality in medical emergency admissions, surgical in-patients, and cardio-pulmonary arrest patients (Cei, Bartolomei, & Mumoli, 2009; Gardner-Thorpe, Love, Wrightson, Walsh, & Keeling, 2006; Li & Ye, 2008; C. Subbe, Falcus, Rutherford, & Gemmell, 2003; C. P. Subbe, Davies, Williams, Rutherford, & Gemmell, 2003; C. P. Subbe, Kruger, Rutherford, & Gemmel, 2001; C. P. Subbe, Slater, Menon, & Gemmell, 2006).

Nurses’ Initial Response to Abnormal Vital Signs

The emergency nurse’s response to abnormal vital signs and the time of response were measured according to the documentation in the chart. The difference between the time that abnormal vital signs were identified and the time of the documented intervention were calculated. When the chart contained abnormal vital signs or adverse changes in vital signs described in a narrative
note by the nurse, this information was recorded. Interventions for changes in vital signs or abnormal vital signs that were documented in the chart were recorded. Anticipated interventions included communication with physician or physician’s assistant, pharmacological interventions (i.e. administration of vasopressor or antihypertensive medication to alter heart rate or rhythm, antibiotics and antipyretics in the presence of fever, administration of pain medications), patient education to reduce hyperventilation or anxiety, distraction or repositioning of the patient to alleviate pain, or the application of cooling or warming devices. Timed interventions were obtained from medication records, narrative notes and physician orders.

Additional Contextual Factors

The complete list of variables that were collected are listed in Table 4. The relationship of any family members in the ED were recorded on the PI designed data collection tool when documented. Because the presence of family members could not be controlled and it was thought that it may impact the frequency with which vital signs are monitored, this information was collected and reported. Family members may request that the nurse recheck the patient’s temperature because they believe the patient feels hot or family members may notify the nurse that the patient is breathing rapidly. This information was obtained from the patient’s registration form and from the nursing narrative section of the chart.

Intra-rater Reliability

To ensure accuracy of the data collected, intra-rater reliability was assessed. The PI was self-trained on extracting data from 10 charts prior to
initiating this study and created a decision sheet to establish decision rules that may result from discrepancies in data (e.g. different ages noted on admission sheet and triage sheet) or missing data. Data on 10% of the sample charts were recollected and compared to the original data collected. Data from every twentieth chart was recollected 2 weeks after the initial chart extraction. The intra-rater reliability was calculated to have 97% agreement.

Table 4. List of data points collected

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source</th>
<th>Measurement Tool</th>
<th>Level of Measurement</th>
<th>Time Collected</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Independent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ED crowding</td>
<td>EMR</td>
<td>EDWIN</td>
<td>Ordinal</td>
<td>Every 4 hours</td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Age</td>
<td>Registration Sheet</td>
<td>PI designed tool</td>
<td>Continuous</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>-Gender</td>
<td>Registration Sheet</td>
<td>PI designed tool</td>
<td>Nominal</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>-Payment method</td>
<td>Registration Sheet</td>
<td>PI designed tool</td>
<td>Nominal</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>-Ethnicity</td>
<td>Registration Sheet</td>
<td>PI designed tool</td>
<td>Nominal</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>Mode of Arrival</td>
<td>Triage note</td>
<td>PI designed tool</td>
<td>Nominal</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>Family presence</td>
<td>Nursing notes</td>
<td>PI designed tool</td>
<td>Continuous</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>Admission diagnosis</td>
<td>Triage note</td>
<td>PI designed tool</td>
<td>Nominal</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>Comorbidities</td>
<td>Triage note</td>
<td>PI designed tool</td>
<td>Continuous</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>Triage category</td>
<td>Triage note</td>
<td>PI designed tool</td>
<td>Interval</td>
<td>Initial chart review</td>
</tr>
<tr>
<td>Baseline vital signs</td>
<td>Triage note</td>
<td>PI designed too</td>
<td>Continuous</td>
<td>Initial chart review</td>
</tr>
<tr>
<td></td>
<td>MEWS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dependent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal vital signs</td>
<td>ED Record</td>
<td>PI designed tool</td>
<td>Continuous</td>
<td>-Every vital sign recorded from triage until 4 hours after ED admission</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MEWS</td>
<td></td>
<td>-Calculated from vital signs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Calculated from times of repeated vital signs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Calculated when abnormal vital sign identified when an intervention is</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>identified</td>
</tr>
<tr>
<td>Length of time between vital signs (in minutes)</td>
<td>ED Record</td>
<td>PI designed tool</td>
<td>Continuous</td>
<td></td>
</tr>
<tr>
<td>Time to intervention (in minutes)</td>
<td>ED record</td>
<td>PI designed tool</td>
<td>Continuous</td>
<td></td>
</tr>
</tbody>
</table>
Human Subjects

The three concerns of human subjects’ research are (a) autonomy, (b) beneficence/ nonmaleficence, and (c) justice (Shamoo & Khin-Maung-Gyi, 2002). Autonomy, or respect for person, requires that subjects made their own decisions regarding their involvement in the study. Researchers are required to provide sufficient information regarding the proposed study in order that prospective subjects may provide informed consent. This concept also allows subjects to consent or refuse to be in the study, or to drop out of the study if they wish. Beneficence (doing good) and nonmaleficence (do no harm) are intertwined concepts that emphasize enhancing the welfare of others. These concepts focus on minimizing the risks to the subjects and providing enough information to allow the prospective subjects to weigh the risks against the benefits of participation in the study. Justice refers to equality of treatment of each person. The selection of subjects should be fair to all individuals without prejudice based on race, gender, social status, decisional incapacity or condition.

This project underwent the human subjects’ Institutional Review Board (IRB) processes at UHCMC. The PI has completed human subjects’ research training. To ensure confidentiality, all data were de-identified. Data collection sheets were devoid of patient identifiers, such as medical record number or date of birth, and contained the assigned code number of the subject in the upper right hand corner of each page. The researcher maintained human subjects training via the Continuing Research Education Credit (CREC) Program through Case Western Reserve University, which provides education in the protection of
human subjects in research. This study was submitted to the IRB of Human Subjects of Case Western Reserve University and UHCMC for approval. There were no physical, social, or economic risks associated with participation in this study. No adult subjects were excluded based on race, gender, socioeconomic status or age. This study did not cause any harm or discomfort to the subjects, nor did it provide direct or individual benefits.

Data Protection

Each subject was assigned a code number. To protect patient confidentiality, subject names and other patient identifiers did not appear on the data collection forms. It was planned that each subject was to have an individually numbered folder that contained the entire patient’s collected data. However, it was quickly realized that the data collection sheets for each subject did not warrant an entire folder. So, the data collection sheets for each patient were maintained in sequential order in a single 3-ring binder. Information on each subject was placed in a locked file in a secure research office while the list of patient names and subject data was maintained in a separate locked cabinet until the data was cleansed. Following data cleaning, the master list of subject names was destroyed. Data files were maintained on the researcher’s fingerprint-reader secured computer and copied onto a password protected flash drive that were maintained in a secure location where only the primary investigator and co-investigator were able to access the data.
Data Management

After the data were collected, all variables’ values from the subject’s data collection form were manually inputted into the Statistical Package for the Social Sciences (SPSS) 16.0. Univariate descriptive statistics were performed in order to assess the frequency, distribution and variance of each variable and to identify missing values and outliers in the data. Extreme cases that were the result of miscoding and incorrectly entered data were assessed carefully and corrected.

Data Analysis

Data analysis included descriptive analysis to describe each variable and multiple regressions, as well as structural equation modeling to analyze the relationships between the variables. Data was analyzed using AMOS 16 and SPSS version 16.0 (2007).

Descriptive statistics were performed in order to describe each of the study variables as well as the study sample’s characteristics. Statistics obtained for each variable included assessing the distribution of the values (skewness and kurtosis), frequency tables, mean, median, mode, variance and standard deviation of the values.

Research question 1 (Was there an association between the length of time between vital signs recording and differing degrees of ED crowding?) and research question 4 (What effect did the degree of ED crowding have on the measurement of vital signs for a patient in the ED?) were analyzed using linear regression. Research question 2 (On days when the ED was crowded, what factors influenced the frequency with which emergency nurses monitor patients’
vital signs?) used multiple regression and structural equation modeling for data analysis. Research question 3 (What factors influenced the time to the emergency nurse’s initial response when abnormal vital signs were present?) was analyzed using correlations.

Because the dependent variables (length of time between vital signs and time to intervention) were continuous variables, and the multiple independent variables were continuous and dummy-coded categorical, multiple regression was used to analyze the data. A similar study examining the relationship between ED crowding and pain control (Pines & Hollander, 2008) used logistical regression as the data analysis method. Both of these methods were unacceptable for the purposes of this study because the outcome variable was not categorical. Therefore, multiple regression analysis was used. The frequency tables and partial plot graphs, produced by SPSS, were used to describe the characteristics of the study subjects and determine if the primary assumptions for a linear regression were satisfied. From this information, a preliminary path analysis was created. The regression program of SPSS was used to run the final model path analysis and determined the presence of any predictive relationships among the variables included in this study.

The assumptions of multiple/bivariate regression were tested. The three primary and two secondary assumptions of regression were analyzed. The three primary assumptions that affect the descriptive statistics of multiple regression that were tested were: (a) variance among the variables, (b) identification and/or elimination of influential cases (outliers), and (c) linear relationships among the
variables. The two secondary assumptions that affect the inferential statistics were constant error variance (homoscedasticity) and normality of the error.

Structural equation modeling (SEM) was used to explore the interrelationships between all of the variables in the model for Research Question 2. SEM was selected for this analysis because it allowed for the evaluation of an entire hypothesized multivariate model. SEM adjusted for measurement errors and co-variances while allowing for causal processes to be examined by combining path analysis with multiple regression (Musil, Jones, & Warner, 1998). SEM has distinct advantages over other forms of analysis. Using SEM allowed for more precise estimation of the indirect effects of the predictor variables on the outcome variables (Musil, Jones, & Warner, 1998).

SEM also allowed for the assessment of the overall model using four goodness of fit measures (a) Chi-Square, (b) the Comparative Fit Index (CFI), (c) the Root-Mean-Square Error of Approximation (RMSEA) and (d) the Tucker-Lewis Index (TLI). The Chi-Square was the most basic of the fit statistics used in the analysis. A Chi-Square value that approaches zero was indicative of a model that fit the data well (Kline, 2005). However, the Chi Square was strongly affected by the sample size, the degrees of freedom and the size of the correlations within the model. The CFI was an estimate that used a maximum-likelihood solution and one of the most widely used fit indices in SEM. The CFI assessed the relative improvement in the fit of the hypothesized model from a baseline model without assuming a zero error approximation. A baseline model assumed a zero covariances among the observed variables (Kline, 2005). For this index, higher
values indicate a better fitting model. A score of 0.90 was acceptable while a score of 0.95 or higher was considered to be evidence of an excellent fit of the model to the data (Byrne, 2001). The RMSEA measured the discrepancies related to the degrees of freedom within the model while favoring a simpler model (Kline, 2005, p137). The RMSEA approximated a non central chi-square distribution which meant that the fit of the model into the population was not assumed to be exact. Because this was a measure of error, lower values were indicative of a better fitting model. An RMSEA of 0.08 was considered fair while a value of 0.05 or less indicated that the model had a close approximate fit in the population (Kline, 2005, p 139). The TLI was an incremental fit index that corrected for model complexity. A value for the TLI of .90 was considered acceptable, while values close to 0.95 were indicative of a better fitting model (Byrne, 2001, p 83).

Relationships were examined between the EDWIN score and (a) adverse changes in patients’ vital signs, (b) time between vital signs, and (c) documentation of the nurse acknowledging abnormal or degree of adverse changes in vital signs. Additionally, the presence and acknowledgement of abnormal or degree of adverse changes in vital signs were also examined in relationship to demographic information, patient health status, arrival information and contextual variables using multiple regression.

Missing documentation data were treated as if no documentation was performed and no observation was made by the nurse. Previous studies have replaced missing time data (i.e. order time and insertion time) with the earliest
time written in the medical record notes nearest to the assessment or administration note (Pines, 2006). If 20% or more of the target data points were missing, the chart was excluded from the analysis and replaced with the next chart in the random selection queue. In the SEM analysis, Full Information Maximum Likelihood was used to handle missing data.
Chapter 4
The Results

The primary purpose of this study was to examine patients’ vital signs, and what factors influence the length of time between vital sign recordings during various levels of ED crowding. Secondary purposes included exploring the nurse’s response when vital signs were abnormal and the effect of ED crowding on the occurrence of abnormal vital signs. The research questions for this study were:

RQ1. Was there an association between the length of time between vital signs recording and differing degrees of ED crowding?

RQ2. On days when the ED was crowded, what factors influenced the frequency with which emergency nurses monitored patients’ vital signs?

RQ3. What factors influenced the time to the emergency nurse’s initial response when abnormal vital signs were present?

RQ4. What effect did the degree of ED crowding have on the measurement of vital signs for a patient in the ED?

Sample

Selection. A list of all patients presenting to the ED during the weeks of January 11 -17, 2009, March 8-14, 2009, June 14-20, 2009 and October 11-17, 2009 was input into Microsoft Excel. Each day was divided into six 4-hour time periods. Each subject had to be present in the ED for at least 2 hours in a time period to be included in that time period. For example, if a subject arrived in the ED at 5am and was discharged at 11:45am they would be included in the 3am to
7am and the 7am to 11am period but not the 11am to 3pm period. Once all subjects were assigned to the time period(s) to which they were present, a filter was applied to the dataset so that only the subjects present during that period were selected. For each time period, the number of subjects in each triage category, the numbers of doctors and the number of physician assistants were recorded. EDWIN scores were calculated for each time period. Of the 168 time periods examined only 26 (16%) were not crowded (EDWIN <2). Because there were so few periods where crowding was not present, subjects were selected from both crowded and noncrowded periods separately to ensure that both crowding conditions were represented. Twelve time periods were randomly selected from the crowded time periods list using a random number generator (random.org). The process was repeated to randomly select 4 time periods from the noncrowded periods. The 4 noncrowded periods had only 73 subjects. Since the target was 60 charts from the noncrowded periods to allow for missing/incomplete charts, the random selection process was used to de-select 13 charts rather than select 60 for inclusion. From the crowded periods, 165 out of a possible 3727 charts were randomly selected. A total of 225 charts were requested from Medical Records Department with the goal of locating 200 complete charts that met inclusion criteria. Twelve charts were not available at the time of the review for various reasons (i.e. physician reviews, unable to locate). Six charts were missing the triage assessment paperwork. Five charts were for subjects that did not meet inclusion criteria (e.g. length of stay less than
3 hours). Two hundred and two charts were reviewed of adult patients seen at this academic emergency department.

**Sample size.** Two hundred and twelve charts were reviewed for this study. Of the charts selected, 202 had enough data to be included in the study. The charts that were not included in the study were excluded because length of stay was less than three hours or triage assessments were missing. The charts that were excluded because of missing triage paperwork were from the October time periods when the ED had fully implemented the electronic charting system for triage.

**Demographics.** The 202 charts included in the analysis were records of patients with ages ranging from 17 to 94; the mean age was 47.5 (SD=21.50). Females accounted for 69.9% (n=144) of the subjects. Seventy four percent (n=152) were African Americans. Most subjects reported being single (n=144, 55.3%).

The number of comorbidities recorded for each patient ranged from 0 -9 with a mean of 2.52 (SD=1.871). The number of over-the-counter medications reported by patients ranged from 0 to 5 (mean=0.66, SD=1.037). Patients reported taking between 0 and 14 prescription drugs daily (mean=3.26, SD=3.178).

One hundred and thirty one (63.6%) people arrived by private car while 67 arrived by ambulance and 39% (n=79) of patients had family present. Most patients (n=76, 36.9%) listed Medicaid as their primary payment source while Medicare was the second most common (n=60, 26.1%).
The most common presenting complaint was for gastrointestinal issues (n=51, 24.8%). The next most frequent categories were neurological (n=28, 13.6%), pulmonary (n=26, 12.6%) musculoskeletal (n=24, 11.7%) and cardiovascular (n=22, 10.7%). Eighty three people (41.7%) that presented to the ED were assigned a triage category 2 (emergent), while 118 (57.3%) were assigned a 3 (urgent) category and only 1 patient assigned to triage category 1 (resuscitation) remained in the ED long enough to meet inclusion criteria (mean=2.56, SD=.512). The number of routes (i.e. po, iv, ivp, sq) of medication administered to patients ranged from 0 to 5 (M=1.7, SD=1.14). Length of stay in the ED ranged from 47 to 1407 minutes (M=405.1, SD=205.32). Family members were documented as present in 79 cases (38.3%). In 28% of the cases a parent or child of the patient was present. Four percent of patients (n=8) returned within 48 hours of discharge from the ED.

Vital signs

The MEWS score was calculated using five components (temperature, heart rate, systolic blood pressure, respiratory rate, and responsiveness). Scores of four or greater were recognized as needing intervention. In the current study, the MEWS score was calculated three separate times (Triage, first repeated and Discharge). For the 202 subjects the median MEWS for triage, first repeated, and discharge were 2, 2, and 1 respectively. The triage MEWS scores ranged from 0-11 (M=2.2, SD=1.81). First repeated MEWS scores ranged from 0 to 6 (M=1.69, SD=1.00). Discharge MEWS scores ranged from 0-6 (M=1.544, SD=1.00). A summary of the individual vital signs are listed in Table 5.
Table 5. Summary of Vital Signs during all 3 time points collected.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Crowded (N= 450)</th>
<th>Noncrowded (N= 156)</th>
<th>Total (N=606)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Missing</td>
<td>Mean (SD)</td>
<td>Missing</td>
</tr>
<tr>
<td>Temperature</td>
<td>219</td>
<td>36.5 (1.08)</td>
<td>100</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>18</td>
<td>88.8 (17.74)</td>
<td>10</td>
</tr>
<tr>
<td>Systolic Blood</td>
<td>18</td>
<td>132 (25.57)</td>
<td>10</td>
</tr>
<tr>
<td>Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alertness</td>
<td>21</td>
<td>0.1 (.74)</td>
<td>6</td>
</tr>
<tr>
<td>Respiration</td>
<td>25</td>
<td>18.5 (2.60)</td>
<td>13</td>
</tr>
<tr>
<td>SPO2</td>
<td>55</td>
<td>98.5 (3.32)</td>
<td>33</td>
</tr>
<tr>
<td>Pain</td>
<td>98</td>
<td>3.3 (3.0)</td>
<td>33</td>
</tr>
</tbody>
</table>

The length of time between vital signs ranged from 4 to 807 minutes (M=125.52, SD=92.5). The number of times that vital signs were repeated ranged from 1 to 17 (mean/median/mode=4, SD=2.8). Abnormal vital signs were present 121 times. The nurse acknowledged the abnormal vital signs in the chart 47 times. The mean documented reaction time when abnormal vitals were present was 0 minutes with a range of 0 to 6 minutes (SD=0.919).

Factors theorized to influence the length of time between vital sign recordings were (a) age, (b) EDWIN score, (c) number of comorbidities, (d) gender, (e) marital status, (f) race, (g) arrival mode, (h) payment method, (i) number of routes of medications administered in the ED, (j) number of prescriptions medications reported by the patient, (k) number of over-the-counter medications reported by the patient, (l) length of stay in the ED, (m) triage category, and (n) presence of family members. These same factors were theorized to influence the emergency nurse’s response time when abnormal vital signs were present. These factors are summarized in Table 6.
### Table 6. Summary of Factors Theorized to Affect the Length of Time Between Vital Signs

<table>
<thead>
<tr>
<th>Variable</th>
<th>N (missing)</th>
<th>Mean (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of RX meds</td>
<td>191(11)</td>
<td>3.26(3.178)</td>
</tr>
<tr>
<td>Age</td>
<td>202(0)</td>
<td>47.58(21.50)</td>
</tr>
<tr>
<td>Number of comorbidities</td>
<td>201(1)</td>
<td>2.52(1.871)</td>
</tr>
<tr>
<td>Is family present?</td>
<td>202(0)</td>
<td>1.61(0.498)*</td>
</tr>
<tr>
<td>Gender</td>
<td>202(0)</td>
<td>0.29(0.454)*</td>
</tr>
<tr>
<td>Married</td>
<td>199(3)</td>
<td>0.23(0.419)*</td>
</tr>
<tr>
<td>insurance</td>
<td>201(1)</td>
<td>0.23(0.424)*</td>
</tr>
<tr>
<td>African American</td>
<td>200(2)</td>
<td>0.76(0.428)*</td>
</tr>
<tr>
<td>Private car</td>
<td>201(1)</td>
<td>0.65(0.478)*</td>
</tr>
<tr>
<td># routes meds given</td>
<td>200(2)</td>
<td>1.66(1.135)</td>
</tr>
<tr>
<td>Number of OTC meds</td>
<td>192(10)</td>
<td>0.66(1.037)</td>
</tr>
<tr>
<td>Total LOS in minutes</td>
<td>198(4)</td>
<td>405.1(205.3)</td>
</tr>
<tr>
<td>Triage Category</td>
<td>202(0)</td>
<td>2.59(0.512)</td>
</tr>
<tr>
<td>Triage vitals</td>
<td>194(8)</td>
<td>2.196(1.813)</td>
</tr>
<tr>
<td>Time between vital signs</td>
<td>192(10)</td>
<td>125.5(92.59)</td>
</tr>
</tbody>
</table>

* dichotomous variable

### Missing values

The final sample size was 202. All the variables in this analysis had fewer than 10% missing values except temperature. Of the 606 times that temperature was required to calculate the MEWS, the value was missing 319 times. The high occurrence of missing temperatures was observed during the pilot study. It was decided prior to data collection that missing temperatures for the discharge and first repeated vital signs would be assumed to be unchanged from the triage measurement and the triage temperature was substituted for missing temperature recordings. Other missing values were not manipulated.

### Analysis of Research questions

**Research Question 1 Results**

RQ1. Was there an association between the frequency of vital sign recording and differing degrees of ED crowding?

A total of 152 people, 75% of the total study population, were present during periods of crowding. EDWIN scores ranged from 1.73 to 29.25 (M=10.464,
SD=9.995). The length of time between vital signs ranged from 4.2 to 807 minutes with a mean of 125.5 minutes (SD= 92.6).

All variables met the criteria to satisfy the primary and secondary assumptions for regression (Appendix 2). All variables had skewness below 3. Although Kurtosis should be less than 8, it can be as high as 20 without indicating a serious problem (Kline, 2005 p.50). Therefore, skewness and kurtosis were within acceptable limits. Less than 10% of variables were missing. The sample had variance because no response category comprised more than 90% of the total subjects. Although time between vital signs had an outlier of 807 minutes, the Cook’s D value was less than 1, so it was assumed that this value was not an influential case.

Results for Research Question 1

The research question was analyzed using two approaches. First, linear regression analysis was used to develop a model to examine the relationship between the degree of ED crowding (EDWIN score) and the length of time between vital sign recording (see Table 7). The regression examining this relationship indicated that there was a statistically significant relationship between the two variables (r=0.128, p=.039). These findings indicate that as crowding increased, the length of time between vital sign recording also increased. The average time between vital sign recording in this ED was 125 minutes.

Table 7. Summary of Correlation Analysis for EDWIN score on Minutes between Vital Signs (N=192)

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>α (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDWIN</td>
<td>.128</td>
<td>.039*</td>
</tr>
</tbody>
</table>

*p<.05
Next, a \( t \)-test was performed to examine if there was a relationship between the mere presence of crowding and the length of time between vital sign recordings. Because the Levine’s test was significant (\( F = 5.347, p = .022 \)), equal variances were not assumed. The \( t \)-test showed a significant difference (\( t (134) = -2.389, p = .018 \) one tailed), in the length of time between vital signs between patients presenting to the ED during crowded periods (\( M = 132.8, SD = 100.14 \)) and patients presenting to the ED during noncrowded periods (\( M = 103.8, SD = 60.72 \)). Because the \( t \)-value was negative, it can be concluded that the patients presenting to the ED during times of ED crowding had a longer time between vital sign recordings.

Research Question 2 Results

RQ2. On days when the ED was crowded, what factors (i.e. number of prescription medications, age, number of comorbidities, family presence, gender, marital status, insurance status, race, arrival mode, number of routes of medications administered, number of over-the-counter medications reported, length of stay, triage category) influenced the frequency with which emergency nurses monitored patients’ vital signs?

Research Question 2 Descriptives

One hundred and fifty-two charts of subjects that were present during crowded periods were examined. The average patient represented in these charts can be described as unmarried (78%), African American (79%), females (72%) averaging three comorbidities with a mean age of 47.25 years (SD=21.59). The average length of stay was 424 minutes (SD=221.0) or approximately 7
hours. The mean time between vital signs recordings was 132.7 minutes (SD=100.1). Descriptive statistics are detailed in Table 8.

Table 8. Descriptive Statistics for Variables Included in Research Question 2.

<table>
<thead>
<tr>
<th></th>
<th>N (missing)</th>
<th>Mean (s.d.)</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Rx meds</td>
<td>144(8)</td>
<td>3.31(3.11)</td>
</tr>
<tr>
<td>Age</td>
<td>150(2)</td>
<td>47.25(21.6)</td>
</tr>
<tr>
<td>Number of comorbidities</td>
<td>149(3)</td>
<td>2.60(1.91)</td>
</tr>
<tr>
<td>Family present</td>
<td>150(2)</td>
<td>1.61(.504)*</td>
</tr>
<tr>
<td>Gender</td>
<td>150(2)</td>
<td>.28(.451)*</td>
</tr>
<tr>
<td>Married</td>
<td>148(4)</td>
<td>.22(.413)*</td>
</tr>
<tr>
<td>Insurance status</td>
<td>149(3)</td>
<td>.25(.433)*</td>
</tr>
<tr>
<td>African American</td>
<td>149(3)</td>
<td>.79(.412)*</td>
</tr>
<tr>
<td>Private car</td>
<td>149(3)</td>
<td>.67(.471)*</td>
</tr>
<tr>
<td>Number of routes of meds</td>
<td>148(4)</td>
<td>1.76(1.12)</td>
</tr>
<tr>
<td>administered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of OTC meds</td>
<td>145(7)</td>
<td>.61(1.03)</td>
</tr>
<tr>
<td>LOS (mins)</td>
<td>148(4)</td>
<td>424.36(221)</td>
</tr>
<tr>
<td>Triage category</td>
<td>152(0)</td>
<td>2.56(.497)</td>
</tr>
<tr>
<td>Triage vitals</td>
<td>144(8)</td>
<td>2.3333(1.93)</td>
</tr>
<tr>
<td>Time between vital signs</td>
<td>144(8)</td>
<td>132.749(100)</td>
</tr>
</tbody>
</table>

* dichotomous variable

Analysis for Research Question 2

Data were tested for potential violations of the primary and secondary assumptions of regression. After the assumptions were tested, the hypothesized model was tested using multiple regression and structural equation modeling. The results of these tests are detailed below.

*Primary assumptions.* Primary assumptions were tested (see Appendix 3). The frequency tables for each variable were reviewed and normality was verified by examining the skewness and kurtosis for each variable. Two variables, relationship of family member and the number of family members present, were excluded from the analysis because the charts did not have this information documented 67% and 98% of the time respectively. Categorical, nonnumeric
variables (marital status, race, mode of arrival and insurance status) were recoded into dichotomous dummy variables in order to be incorporated into the analysis as predictor variables. (Hair, 2006. p.167). For the whole population and the portion present during crowding, skewness (<3) and kurtosis (<8) were acceptable. No variable had more than 10% missing values (see Appendix 3). The absence of influential cases was tested using residual statistics. Because the Cook’s D value was <1 (max Cook’s D=.583), the assumption that there was no influential case was supported; and no outliers were identified (see Appendix 3). To test for linear relationships among all the variables, partial regression plots were analyzed for each variable against the frequency of vital signs (see Appendix 3). Each graph then had linear, quadratic and cubic lines inserted. If the R-squared value had a 0.02 or greater change between the lines, the variable was transformed and the regression was re-run to see if the modified variable had a significant change on the completed model. Only three variables had nonlinear relationships with the length of time between vital signs: (a) age had a .07 change from linear to cubic, (b) over-the-counter (OTC) medications changed 0.03 between linear and cubic, and (c) number of routes of medications given changed 0.04 between cubic and linear. Because of the nonlinear relationships, the variables were transformed.

Transformation of Age variable. The partial plot analysis revealed that Age did not have a linear relationship with the length of time between vital signs. By examining the partial plot, a bulge to the right was identified that indicated a need to increase the power. The variable was transformed by squaring and cubing the
values to examine if modification of the variable would provide a linear relationship to the outcome variable (Hair, 2006, p173). After transforming the variables, each transformation was included in a regression to see if any changes in the R square occur. There was no significant change in the R squared value when regressions were run using the modified variables (see Appendix 4). Because there were no significant changes in the model from transforming any of the non-linear variables the age variable was further modified by subtracting 16 so that the lowest value for age was 1. This value was then squared and cubed. The regression was run three more times to include age-minus-16, age-minus-16 squared, and age-minus-16 cubed, independently. Again there was no significant change in the model with the modifications to the Age variable. Therefore, the original Age variable was kept in the analysis.

**Transformation of OTC variable.** According to the partial plot graph, the relationship of OTC medications to frequency of vitals bulged to the left, so the OTC variable needed to be powered down. The square root of the variable was computed and examined within the model. The partial plot revealed that taking the square root of the OTC variable improves linearity (see Appendix 5). However, when the modified variable was added to the regression, the changes to the model were not significant and there was no significant change in the R square. Because the transformation of the modified variable added complexity to the model without altering the results, the original value was used in the final regression model.
Transformation of the number of routes of medications given while in the ED. The partial plots for the number of routes of medications given while in the ED were examined and the graph showed a left bulge indicating that this variable needed to be adjusted down. The square root of the variable was analyzed. Replacing the original variable with its square root corrected the non-linearity issue. However, there was no significant change in the R square to warrant changing this variable (see Appendix 6).

Conclusions about transforming variables. The three variables, (a) age, (b) over-the-counter medications, and (c) number of routes of medications given in the ED were transformed. There was not a significant change in the R square for any of the variables to warrant using a modified form. Because of the lack of improvement to the overall regression model with the modification of the variables, the original variables remained unmodified in the model.

Secondary Assumptions. By examining the regression plots, it was apparent that the error values have less than a 3:1 fanning of the values. Looking at the observed values against the expected values it can be seen that the values stay fairly similar (see Appendix 3). At each level of the predictor variables, the variance of the residual terms should be constant (Fields, 2005, p.170). This was assessed by examining the error variances and they were found to be normally distributed. Therefore, the secondary assumptions of regression were satisfied.
Regression analysis for Research Question 2

Table 9
Analysis of Collinearity and Correlations to the Length of Time (min) between Vital Sign Recordings

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>P</th>
<th>Collinearity Statistics</th>
<th>Tolerance</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-.198*</td>
<td>.010</td>
<td>.659</td>
<td>1.517</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>-.125</td>
<td>.073</td>
<td>.892</td>
<td>1.121</td>
<td></td>
</tr>
<tr>
<td>EDWIN</td>
<td>.071</td>
<td>.205</td>
<td>.953</td>
<td>1.050</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>.003</td>
<td>.487</td>
<td>.809</td>
<td>1.236</td>
<td></td>
</tr>
<tr>
<td>Insurance</td>
<td>.034</td>
<td>.347</td>
<td>.836</td>
<td>1.196</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>-.014</td>
<td>.435</td>
<td>.754</td>
<td>1.327</td>
<td></td>
</tr>
<tr>
<td>Private car</td>
<td>.313**</td>
<td>.000</td>
<td>.740</td>
<td>1.352</td>
<td></td>
</tr>
<tr>
<td>Triage category</td>
<td>.258**</td>
<td>.001</td>
<td>.768</td>
<td>1.302</td>
<td></td>
</tr>
<tr>
<td>Number of comorbidities</td>
<td>-.267**</td>
<td>.001</td>
<td>.454</td>
<td>2.202</td>
<td></td>
</tr>
<tr>
<td>Family presence</td>
<td>-.074</td>
<td>.194</td>
<td>.881</td>
<td>1.136</td>
<td></td>
</tr>
<tr>
<td>Total Length of stay in ED</td>
<td>.160*</td>
<td>.031</td>
<td>.946</td>
<td>1.057</td>
<td></td>
</tr>
<tr>
<td>Number of OTC meds</td>
<td>.066</td>
<td>.223</td>
<td>.743</td>
<td>1.345</td>
<td></td>
</tr>
<tr>
<td>Number of Prescription meds</td>
<td>-.259**</td>
<td>.001</td>
<td>.437</td>
<td>2.287</td>
<td></td>
</tr>
<tr>
<td>Number of routes of meds given</td>
<td>-.167*</td>
<td>.025</td>
<td>.916</td>
<td>1.092</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05    **p< .01

Table 10 Explained variance for the Length of Time between Vital Sign Recordings

<table>
<thead>
<tr>
<th>Variable</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>SE Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictors</td>
<td>.508</td>
<td>.258</td>
<td>.166</td>
<td>92.89181</td>
</tr>
</tbody>
</table>

Assessing Multicollinearity. No correlations between the variables were .80 or greater. Therefore it appears that multicollinearity was not an issue. Because no value of the variance inflation factor (VIF) approached 10, the absence of multicollinearity was further supported in this data set. Additionally, no tolerance level was below or approached 0.1 (Fields, p 175).

Structural Equation Modeling analysis for Research Question 2

To better understand the relationships between the variables and the strength of the tested model, the hypothesized model was entered into AMOS 16.0 and structural equation modeling (SEM) was conducted with all the variables (see Figure 8).
Figure 8. Original Hypothetical Model

The original model had several nonsignificant paths. Removing the most nonsignificant covariance paths considerably increased the goodness of fit for the overall model (see Table 11). First, the nonsignificant covariances (p > 0.10) were removed. Next, regression paths were removed one step at a time, the most nonsignificant one paths were removed first. Whenever, a non significant regression path was removed from the model, the path analysis was reanalyzed after each modification to ensure that the fit was improving with each change. The first 20 deletions improved all goodness of fit indices. Further deletions slightly decreased some goodness-of-fit indices that are affected by the changes.
in the degrees of freedom. Because the values remained excellent fits overall, the deletions were kept in order to make the most parsimonious model possible while maintaining excellent goodness-of-fit values. Goodness-of-fit indices were examined to determine the acceptability of the model. Guidelines for an acceptable fit are a Comparative Fit Index (CFI) higher than 0.90 with 0.95 being considered excellent fit, a Tucker Lewis Index (TLI) higher than 0.90 and 0.95 being considered an excellent fit, and the Root Mean Square Error of Approximation (RMSEA) lower than 0.08 being fair and 0.05 being excellent (Musil, Jones, Warner, 1998). Once all nonsignificant regression paths were deleted, covariances were re-examined and nonsignificant correlations were systematically deleted. Regression weights were then re-examined following each deletion to ensure that the deletions did not improve the significance of other regression paths. Because family presence did not correlate with any other variables, the variable was removed completely and the analysis was rerun. Variables that had all regression weights removed due to insignificant paths were then systematically removed from the model and the analysis was rerun after each deletion. The final model depicting all significant correlations is shown in Figure 9.

Table 11. Results of Goodness of Fit Indices with Removal of Nonsignificant paths.

<table>
<thead>
<tr>
<th>Step: path removed</th>
<th>$X^2$</th>
<th>p</th>
<th>Df</th>
<th>RMSEA</th>
<th>CFI</th>
<th>TLI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original model</td>
<td>7.277</td>
<td>.007</td>
<td>1</td>
<td>.177</td>
<td>.980</td>
<td>.811</td>
</tr>
<tr>
<td>1. Removed all non sig covariances</td>
<td>32.168</td>
<td>.276</td>
<td>20</td>
<td>.029</td>
<td>.990</td>
<td>.952</td>
</tr>
<tr>
<td>2. Removed family presence to los</td>
<td>32.169</td>
<td>.331</td>
<td>21</td>
<td>.023</td>
<td>.993</td>
<td>.969</td>
</tr>
<tr>
<td>3. Remove gender to routes</td>
<td>32.180</td>
<td>.409</td>
<td>22</td>
<td>.020</td>
<td>.994</td>
<td>.970</td>
</tr>
<tr>
<td>4. Remove comorbidities and los</td>
<td>32.183</td>
<td>.418</td>
<td>23</td>
<td>.011</td>
<td>.996</td>
<td>.987</td>
</tr>
<tr>
<td>5. Remove rx to los</td>
<td>32.196</td>
<td>.424</td>
<td>24</td>
<td>.000</td>
<td>.996</td>
<td>.990</td>
</tr>
<tr>
<td>6. Removed married to</td>
<td>34.219</td>
<td>.473</td>
<td>25</td>
<td>.000</td>
<td>1.00</td>
<td>1.001</td>
</tr>
<tr>
<td></td>
<td>Remove otc to triage</td>
<td>Remove insurance to triage</td>
<td>Remove AA to triage</td>
<td>Remove Private car to LOS</td>
<td>Remove insurance to los</td>
<td>Remove family to routes</td>
</tr>
<tr>
<td>7.</td>
<td>22.237</td>
<td>.725</td>
<td>26</td>
<td>.000</td>
<td>1.00</td>
<td>1.051</td>
</tr>
<tr>
<td>8.</td>
<td>22.277</td>
<td>.768</td>
<td>27</td>
<td>.000</td>
<td>1.00</td>
<td>1.059</td>
</tr>
<tr>
<td>9.</td>
<td>22.404</td>
<td>.803</td>
<td>28</td>
<td>.000</td>
<td>1.00</td>
<td>1.066</td>
</tr>
<tr>
<td>10.</td>
<td>22.585</td>
<td>.865</td>
<td>29</td>
<td>.000</td>
<td>1.00</td>
<td>1.075</td>
</tr>
<tr>
<td>11.</td>
<td>22.486</td>
<td>.867</td>
<td>30</td>
<td>.000</td>
<td>1.00</td>
<td>1.079</td>
</tr>
<tr>
<td>12.</td>
<td>22.533</td>
<td>.892</td>
<td>31</td>
<td>.000</td>
<td>1.00</td>
<td>1.085</td>
</tr>
<tr>
<td>13.</td>
<td>22.559</td>
<td>.914</td>
<td>32</td>
<td>.000</td>
<td>1.00</td>
<td>1.091</td>
</tr>
<tr>
<td>14.</td>
<td>22.650</td>
<td>.931</td>
<td>33</td>
<td>.000</td>
<td>1.00</td>
<td>1.096</td>
</tr>
<tr>
<td>15.</td>
<td>22.852</td>
<td>.956</td>
<td>34</td>
<td>.000</td>
<td>1.00</td>
<td>1.105</td>
</tr>
<tr>
<td>16.</td>
<td>22.997</td>
<td>.965</td>
<td>35</td>
<td>.000</td>
<td>1.00</td>
<td>1.109</td>
</tr>
<tr>
<td>17.</td>
<td>23.304</td>
<td>.971</td>
<td>36</td>
<td>.000</td>
<td>1.00</td>
<td>1.112</td>
</tr>
<tr>
<td>18.</td>
<td>23.682</td>
<td>.975</td>
<td>37</td>
<td>.000</td>
<td>1.00</td>
<td>1.114</td>
</tr>
<tr>
<td>19.</td>
<td>23.862</td>
<td>.980</td>
<td>38</td>
<td>.000</td>
<td>1.00</td>
<td>1.116</td>
</tr>
<tr>
<td>20.</td>
<td>25.271</td>
<td>.986</td>
<td>39</td>
<td>.000</td>
<td>1.00</td>
<td>1.119</td>
</tr>
<tr>
<td>21.</td>
<td>25.402</td>
<td>.989</td>
<td>40</td>
<td>.000</td>
<td>1.00</td>
<td>1.122</td>
</tr>
<tr>
<td>22.</td>
<td>25.657</td>
<td>.991</td>
<td>41</td>
<td>.000</td>
<td>1.00</td>
<td>1.124</td>
</tr>
<tr>
<td>23.</td>
<td>25.852</td>
<td>.993</td>
<td>42</td>
<td>.000</td>
<td>1.00</td>
<td>1.126</td>
</tr>
<tr>
<td>24.</td>
<td>26.096</td>
<td>.994</td>
<td>43</td>
<td>.000</td>
<td>1.00</td>
<td>1.128</td>
</tr>
<tr>
<td>25.</td>
<td>26.409</td>
<td>.995</td>
<td>44</td>
<td>.000</td>
<td>1.00</td>
<td>1.130</td>
</tr>
<tr>
<td>26.</td>
<td>26.891</td>
<td>.996</td>
<td>45</td>
<td>.000</td>
<td>1.00</td>
<td>1.130</td>
</tr>
<tr>
<td>27.</td>
<td>27.423</td>
<td>.996</td>
<td>46</td>
<td>.000</td>
<td>1.00</td>
<td>1.130</td>
</tr>
<tr>
<td>28.</td>
<td>28.161</td>
<td>.996</td>
<td>47</td>
<td>.000</td>
<td>1.00</td>
<td>1.129</td>
</tr>
<tr>
<td>29.</td>
<td>29.724</td>
<td>.994</td>
<td>48</td>
<td>.000</td>
<td>1.00</td>
<td>1.124</td>
</tr>
<tr>
<td>30.</td>
<td>30.466</td>
<td>.994</td>
<td>49</td>
<td>.000</td>
<td>1.00</td>
<td>1.123</td>
</tr>
<tr>
<td>31.</td>
<td>31.320</td>
<td>.994</td>
<td>50</td>
<td>.000</td>
<td>1.00</td>
<td>1.121</td>
</tr>
<tr>
<td>32.</td>
<td>32.411</td>
<td>.993</td>
<td>51</td>
<td>.000</td>
<td>1.00</td>
<td>1.118</td>
</tr>
<tr>
<td>33.</td>
<td>33.460</td>
<td>.993</td>
<td>52</td>
<td>.000</td>
<td>1.00</td>
<td>1.116</td>
</tr>
<tr>
<td>34.</td>
<td>34.312</td>
<td>.993</td>
<td>53</td>
<td>.000</td>
<td>1.00</td>
<td>1.115</td>
</tr>
<tr>
<td>35.</td>
<td>35.798</td>
<td>.990</td>
<td>54</td>
<td>.000</td>
<td>1.00</td>
<td>1.110</td>
</tr>
<tr>
<td>36.</td>
<td>38.153</td>
<td>.984</td>
<td>55</td>
<td>.000</td>
<td>1.00</td>
<td>1.102</td>
</tr>
<tr>
<td>37.</td>
<td>39.958</td>
<td>.978</td>
<td>56</td>
<td>.000</td>
<td>1.00</td>
<td>1.096</td>
</tr>
<tr>
<td>38.</td>
<td>42.795</td>
<td>.963</td>
<td>57</td>
<td>.000</td>
<td>1.00</td>
<td>1.086</td>
</tr>
<tr>
<td>39.</td>
<td>45.696</td>
<td>.940</td>
<td>58</td>
<td>.000</td>
<td>1.00</td>
<td>1.076</td>
</tr>
<tr>
<td>40.</td>
<td>48.918</td>
<td>.904</td>
<td>59</td>
<td>.000</td>
<td>1.00</td>
<td>1.064</td>
</tr>
<tr>
<td>41.</td>
<td>53.494</td>
<td>.845</td>
<td>60</td>
<td>.000</td>
<td>1.00</td>
<td>1.051</td>
</tr>
<tr>
<td>42.</td>
<td>55.725</td>
<td>.812</td>
<td>61</td>
<td>.000</td>
<td>1.00</td>
<td>1.045</td>
</tr>
<tr>
<td>43.</td>
<td>57.302</td>
<td>.795</td>
<td>62</td>
<td>.000</td>
<td>1.00</td>
<td>1.042</td>
</tr>
<tr>
<td>44.</td>
<td>59.804</td>
<td>.750</td>
<td>63</td>
<td>.000</td>
<td>1.00</td>
<td>1.035</td>
</tr>
<tr>
<td>45.</td>
<td>58.534</td>
<td>.669</td>
<td>64</td>
<td>.000</td>
<td>1.00</td>
<td>1.023</td>
</tr>
<tr>
<td>46.</td>
<td>49.887</td>
<td>.634</td>
<td>54</td>
<td>.000</td>
<td>1.00</td>
<td>1.019</td>
</tr>
<tr>
<td>47.</td>
<td>45.473</td>
<td>.536</td>
<td>47</td>
<td>.000</td>
<td>1.00</td>
<td>1.011</td>
</tr>
<tr>
<td>48.</td>
<td>41.990</td>
<td>.385</td>
<td>40</td>
<td>.016</td>
<td>.988</td>
<td>.984</td>
</tr>
</tbody>
</table>
Results for Research Question 2

Fourteen predictor variables were included in the multiple regression and structural equation model to explore this research question. After transforming three variables to correct for nonlinearity issues independently, it was determined that the increased complexity that would be present because of the variable modifications did not increase the strength of the model. So the original variables were used.

Regression results. The regression showed that the time between vital sign recordings could be predicted by length of stay, age, and triage category.
But there were also causal relationships with number of comorbidities, the number of prescription medications that the patient reported, the number of routes that medications were administered to the patient while in the ED, and the presence of abnormal vital signs (as represented by MEWS score). Although many of the variables correlated with each other, collinearity statistics showed that multicollinearity was not a problem in this analysis (see Table 9). The length of time between vital signs increased as the triage category was less acute ($r = .258, p = .001$), the subjects required fewer routes of medication to be administered in the ED ($r = -.167, p = .025$) the number of prescription medications decreased ($r = -.259, p = .001$) and as the number of comorbidities decreased ($r = -.267, p = .001$). Patients had more frequent vital sign recordings when abnormal vital signs were recorded ($r = 0.236, p = .003$) and as age increased ($r = -.198, p = .010$). The analysis showed that patients that arrived in private cars had a greater length of time between vital sign recording ($r = .313, p < .001$).

**SEM results.** The goodness-of-fit indices for the final model were a CFI of 1.0, a TLI 1.0 and a RMSEA of .000. The $p$ value for the final model was 0.669 which was nonsignificant, meaning that there was no difference between the model and the data. The variables that had a direct effect on the length of time between vital signs were (a) triage category, (b) EDWIN score, (c) length of stay, (d) number of routes of medications administered in the ED, (e) number of comorbidities, and (f) arrival in a private car (see Table 12). Covariances among the independent variables are listed in Table 13.
Examining the regression weights shows that there were five predictor variables (length of stay, number of medication routes, crowding level, number of comorbidities and triage category) that have a significant impact on the length of time between vital sign recordings. These results differ slightly from the regression model initially used. Age was a significant predictor for the length of time between vital signs in the original regression, but not in the SEM results. This was explained by the effect of triage category. Age, gender and number of comorbidities all have significant relationship to triage category, but the
regression weights were not strong enough to be considered significant predictors of the length of time between vital signs. The time between vital signs increased by 5 seconds for each increase of 1 minute in the length of stay.

Triage category and arrival mode had the greatest impact on the time between vital signs. The time between vital signs increased by 35 minutes for patients that arrived to the ED in a private car (vs. ambulance). Similarly, for every increase of one in the triage category (became less acute) the time between vital signs increased by 35 minutes. Patients that received medications in the ED by more routes (i.e. po, IV, im) had a decrease in the average length of time between the vital signs recordings by 13 minutes. The time between vital signs decreased by 7 minutes when the number of comorbidities reported by the patient increased by one. As length of time or the EDWIN score increased by 1, the length of time between vital signs increased by 0.88 and 1.33 minutes respectively.

Research Question 3 Results

RQ3. What factors (i.e. number of prescription medications, age, number of comorbidities, family presence, gender, marital status, insurance status, race, arrival mode, number of routes of medications administered, number of over-the-counter medications reported, length of stay, triage category) influenced the time to the emergency nurse’s initial response when abnormal vital signs were present?
Descriptive for Research Question 3

Abnormal vital signs were present in 121 patients. However, in 76 charts, there was no associated note in the chart from the ED staff that acknowledged the abnormality of the vital signs. These 76 charts were excluded from analysis because no response time could be assigned. In the 47 charts with clear notation of vital sign abnormality, two charts had illegible times recorded for a response initiated by the nurse related to the abnormal vital sign recording. The most common response to abnormal vital signs were notifying the attending physician (n=22), medicating as ordered by the physician (n=15), and continued monitoring of the patient (n=5).

For this research question the sample was 45 complete charts which were not enough to conduct the planned multiple regression analysis. However, correlations between the time to the nurse’s response to abnormal vital signs and the hypothesized predictor variables were examined. Normality and variance analysis was performed on all variables prior to conducting correlation analysis and are listed in Table 14. All variables have adequate variance and were normally distributed (Skewness < 3, Kurtosis < 8).
Table 14. Descriptive stats for Research Question 3 variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>N (missing)</th>
<th>Mean (s.d.)</th>
<th>Skewness (s.e.)</th>
<th>Kurtosis (s.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comorbidities</td>
<td>45 (0)</td>
<td>2.98 (2.09)</td>
<td>.279 (.354)</td>
<td>.015 (.695)</td>
</tr>
<tr>
<td>Triage Vitals</td>
<td>43 (2)</td>
<td>2.58 (1.91)</td>
<td>1.76 (.361)</td>
<td>4.47 (.709)</td>
</tr>
<tr>
<td>Age</td>
<td>45 (0)</td>
<td>52.56 (20.64)</td>
<td>.164 (.354)</td>
<td>-6.46 (.695)</td>
</tr>
<tr>
<td>EDWIN</td>
<td>45 (0)</td>
<td>7.52 (9.23)</td>
<td>1.76 (.354)</td>
<td>1.52 (.695)</td>
</tr>
<tr>
<td>First Vitals</td>
<td>44 (1)</td>
<td>1.80 (1.02)</td>
<td>1.11 (.357)</td>
<td>.652 (.702)</td>
</tr>
<tr>
<td>Frequency of Vitals</td>
<td>45 (0)</td>
<td>76.4 (40.2)</td>
<td>2.06 (.354)</td>
<td>7.42 (.695)</td>
</tr>
<tr>
<td>Gender</td>
<td>45 (0)</td>
<td>38 (49)*</td>
<td>.522 (.354)</td>
<td>-1.81 (.695)</td>
</tr>
<tr>
<td>Married</td>
<td>45 (0)</td>
<td>38 (49)*</td>
<td>.522 (.354)</td>
<td>-1.81 (.695)</td>
</tr>
<tr>
<td>African American</td>
<td>45 (0)</td>
<td>80 (40.5)*</td>
<td>-1.55 (.354)</td>
<td>.426 (.695)</td>
</tr>
<tr>
<td>Private Car</td>
<td>45 (0)</td>
<td>56 (50.3)*</td>
<td>-2.31 (.354)</td>
<td>2.04 (.695)</td>
</tr>
<tr>
<td>Insurance</td>
<td>45 (0)</td>
<td>16 (36.7)*</td>
<td>1.97 (.354)</td>
<td>1.95 (.695)</td>
</tr>
<tr>
<td>Number of Routes</td>
<td>45 (0)</td>
<td>2.44 (1.24)</td>
<td>-3.40 (.354)</td>
<td>.369 (.695)</td>
</tr>
<tr>
<td>Rx meds</td>
<td>42 (3)</td>
<td>3.6 (3.47)</td>
<td>.781 (.365)</td>
<td>-.045 (.717)</td>
</tr>
<tr>
<td>OTC meds</td>
<td>42 (3)</td>
<td>1.24 (.79)</td>
<td>1.96 (.365)</td>
<td>3.55 (.717)</td>
</tr>
<tr>
<td># Vitals Repeated</td>
<td>45 (0)</td>
<td>6.33 (3.28)</td>
<td>1.51 (.354)</td>
<td>3.34 (.695)</td>
</tr>
<tr>
<td>LOS</td>
<td>45 (0)</td>
<td>427.7 (223.84)</td>
<td>1.51 (.354)</td>
<td>3.76 (.695)</td>
</tr>
<tr>
<td>Triage Category</td>
<td>45 (0)</td>
<td>2.47 (5.05)</td>
<td>.138 (.354)</td>
<td>-2.08 (.695)</td>
</tr>
<tr>
<td>Family present</td>
<td>45 (0)</td>
<td>1.56 (5.03)*</td>
<td>-2.31 (.354)</td>
<td>-2.04 (.695)</td>
</tr>
<tr>
<td>Reaction time</td>
<td>45 (0)</td>
<td>11.27 (12.3)</td>
<td>1.28 (.354)</td>
<td>1.19 (.695)</td>
</tr>
</tbody>
</table>

*a* dichotomous variable

Table 15. Correlations between the Time from Abnormal vital sign acknowledgement to Reaction time

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pearson</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of comorbidities</td>
<td>-.120</td>
<td>.462</td>
</tr>
<tr>
<td>Triage vitals</td>
<td>-.138</td>
<td>.395</td>
</tr>
<tr>
<td>Age</td>
<td>-.270</td>
<td>.092</td>
</tr>
<tr>
<td>EDWIN score</td>
<td>-.180</td>
<td>.266</td>
</tr>
<tr>
<td>First repeated vitals</td>
<td>-.021</td>
<td>.897</td>
</tr>
<tr>
<td>Frequency of vital sign recording</td>
<td>-.061</td>
<td>.709</td>
</tr>
<tr>
<td>Gender</td>
<td>-.069</td>
<td>.674</td>
</tr>
<tr>
<td>Number of Rx meds</td>
<td>.065</td>
<td>.690</td>
</tr>
<tr>
<td>number of routes meds given in ED</td>
<td>.199</td>
<td>.218</td>
</tr>
<tr>
<td>Number of OTC meds</td>
<td>.173</td>
<td>.286</td>
</tr>
<tr>
<td>number of times vitals repeated</td>
<td>-.123</td>
<td>.450</td>
</tr>
<tr>
<td>Total LOS in minutes</td>
<td>-.145</td>
<td>.371</td>
</tr>
<tr>
<td>Arrival by private car</td>
<td>-.019</td>
<td>.905</td>
</tr>
<tr>
<td>African American</td>
<td>.156</td>
<td>.337</td>
</tr>
<tr>
<td>Private insurance</td>
<td>.114</td>
<td>.482</td>
</tr>
<tr>
<td>Married</td>
<td>.014</td>
<td>.932</td>
</tr>
<tr>
<td>Triage Category</td>
<td>.073</td>
<td>.655</td>
</tr>
<tr>
<td>Is family present?</td>
<td>.002</td>
<td>.992</td>
</tr>
</tbody>
</table>

a. List wise N=45

None of the variables had significant correlations to the emergency nurse's response to abnormal vital signs.
Research Question 4 Results

RQ4. What effect did the degree of ED crowding have on the measurement of vital signs for a patient in the ED?

Linear regressions were used to address this question and to develop a model to examine the relationship between the EDWIN score and the length of time between vital sign recording.

Descriptive Statistics. The average EDWIN score was 10.5 for all time periods examined in the study. The average Triage MEWS was 2.2. The average MEWS values became lower with each repeated vital sign recording. The average first repeated MEWS was 1.7 and the discharge MEWS decreased to 1.5. The assumptions of multiple regression were tested and all variables were within acceptable ranges (see Table 16).

Results for Research Question 4.

Regression analysis was performed with the EDWIN value on each MEWS value individually. Table 16 summarizes descriptive values for the variables of interest. Table 17 details the results of the regression analysis. No significant correlations were identified between the EDWIN score and the MEWS value. Although no significant correlations were identified between the EDWIN score and MEWS values, when the individual vital signs were examined, there was a significant decrease in the heart rate and increase in the respiratory rate from triage to discharge (see Table 18).
Table 16. Descriptive statistics for Research Question 4

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Skewness (s.e.)</th>
<th>Kurtosis (s.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDWIN</td>
<td>10.51 (10.03)</td>
<td>.856 (.171)</td>
<td>-.885 (.341)</td>
</tr>
<tr>
<td>Abnormal Vitals</td>
<td>1.38 (.486)</td>
<td>.515 (.175)</td>
<td>-1.753 (.347)</td>
</tr>
<tr>
<td>Present</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triage MEWS</td>
<td>2.200 (1.813)</td>
<td>2.539 (.175)</td>
<td>8.383 (.347)</td>
</tr>
<tr>
<td>1st Repeated MEWS</td>
<td>1.696 (1.000)</td>
<td>1.301 (.175)</td>
<td>1.614 (.347)</td>
</tr>
<tr>
<td>Discharge MEWS</td>
<td>1.545 (1.004)</td>
<td>1.960 (.176)</td>
<td>4.102 (.350)</td>
</tr>
</tbody>
</table>

Table 17. Results of Regressions of EDWIN score on Vital signs (MEWS)

<table>
<thead>
<tr>
<th></th>
<th>R(p)</th>
<th>SE β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triage MEWS</td>
<td>.026 (.359)</td>
<td>1.82</td>
</tr>
<tr>
<td>First repeated MEWS</td>
<td>.046 (.262)</td>
<td>1.00</td>
</tr>
<tr>
<td>Discharge MEWS</td>
<td>.005 (.475)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*One-tailed Pearson Correlation

Table 18. The Effect of Crowding on changes in Individual Vital Signs.

<table>
<thead>
<tr>
<th></th>
<th>R (p)</th>
<th>Confidence Interval</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td></td>
</tr>
<tr>
<td>Change in Heart rate</td>
<td>-.122 (.047)*</td>
<td>-.386</td>
<td>.031</td>
<td></td>
</tr>
<tr>
<td>Change in Resp rate</td>
<td>.170 (.009)**</td>
<td>-.068</td>
<td>.019</td>
<td></td>
</tr>
<tr>
<td>Change in Systolic BP</td>
<td>-.012 (.43)</td>
<td>-.328</td>
<td>.280</td>
<td></td>
</tr>
<tr>
<td>Change in SPO2</td>
<td>-.054 (.251)</td>
<td>-1.06</td>
<td>.522</td>
<td></td>
</tr>
<tr>
<td>Change in Pain</td>
<td>.057 (.259)</td>
<td>-.117</td>
<td>.232</td>
<td></td>
</tr>
</tbody>
</table>

*p<.05 **p<.01
CHAPTER 5

Discussion

The primary purpose of this study was to examine patients’ vital signs and what factors influence the length of time between vital sign recordings during various levels of ED crowding. Secondary purposes included exploring the nurse’s response when vital signs were abnormal and the effect of ED crowding on occurrence of abnormal vital signs. A retrospective chart review was performed as a part of this study. The review required crowding levels to be calculated for 4-hour time intervals. Crowded time periods, as denoted by EDWIN scores over 2.0, were selected from four weeks over the course of one year. Charts were then randomly selected from those time periods. Because so many of the time periods had high EDWIN scores, all of the time periods with EDWIN scores under 2.0 were included from the predetermined time periods and charts were randomly selected from them to be included in the noncrowded group. Data were manually extracted from the charts by one researcher.

Setting and Sample

The setting for hospital records was an urban academic medical center with Magnet status. The sample for this project had a high percentage of minorities (e.g. African American) reflecting the population of the urban environment of the city in which the hospital was located. The sample size and characteristics were next examined for similarities and differences in published reports related to care in the ED.
Sample size. The sample size of this study was smaller than six previous studies of ED crowding. The largest sample sizes occurred from statewide or nationwide databases or accrued data over several years (Pines, et al, 2006; Schull et.al 2004; Pines & Hollander, 2008; Sun et al, 2000; Chalfin et al, 2007; Diercks, et al, 2007). However, the sample size of this study is comparable to the size of six other studies that only examined subjects from a single hospital or from a single year (i.e., ranges of 147-405) (Fee, Weber, Maak, & Bacchetti, 2007; Hwang, Richardson, Sonuyi & Morrison, 2006; Baldursdottir & Jonsdottir, 2002; Vieth & Rhodes, 2006; Goldhill, White, & Sumner, 1999; Mariani, Saeed, Potti, Hebert, Sholes, Lewis, & Hanley, 2006).

Sample Characteristics. The charts reviewed for this project represented a diverse sample. Patient characteristics for this study mirror the national reports with African Americans making up 74% of the sample in both populations (Niska, Bhuiya & Xu, 2010). Females comprised 70% of the subjects with an average age of 48 years. Only 4% of patients seen in the ED returned within 2 days for re-evaluation. Previous reports have the readmission rate as high as 8% (Patient Safety Authority, 2010). Acuity scores and vital sign measurements were also similar to national averages.

The Institute for Healthcare Improvement (IHI) and previous studies report that patients with a MEWS score of 4 need intervention while a score of 5 is critical (Subbe, Kruger, Rutherford & Gemmel, 2001). In the current study, the median MEWS for triage, first repeated, and discharge were 2, 2, and 1 respectively. Similarly, Subbe et al. (2001) reported a median MEWS score for
that study of 1. Because the range of valid MEWS scores is from 0 to 14, the
difference between the median averages from the two populations was
analogous.

This project uniquely provides information about MEWS scores in the ED
over time. The scores demonstrated little variation. A potential explanation for the
similarity between the triage and first repeated MEWS is most likely explained by
decision rules around missing data. Specifically, the triage temperature was used
for missing temperature in the set of first repeated vital signs by the researcher.
Re-assessing temperatures is not a common practice in the ED unless the
patient presents with a fever, has a change in health status, or has an infectious
illness (O. Simpson, RN, LNC, personal communication, November 20, 2010).
Additionally, missing responsiveness was inferred for the MEWS calculation.
While conducting the pilot study, the differences between the responsiveness
assessments on the triage form and the MEWS requirement was noted.
Therefore, it was assumed that any deviation from normal alertness would have
been documented in the triage assessment. Fourteen percent of patients had a
MEWS of 4 or greater in triage. This was less than the results found by Gardner-
Thorpe, Love, Wrightson, Wash and Keeling (2006) that reported 22% of patients
entering the ED had an elevated MEWS score. Perhaps excluding patients with
lower MEWS scores would provide useful insight into determining how ED
crowding affects the care of patients more at risk of deterioration.

The most common presenting complaint was for gastrointestinal issues in
this study. The next four most common categories in descending order were
neurological, pulmonary, musculoskeletal, and cardiovascular. This grouping was similar to previous reports once minor orthopedic injuries were excluded (Grafstein, Innes, Westman, Christenson & Thorne, 2003). Comparing presenting complaints from this study to previous studies focused on ED crowding was difficult because most of the studies were for patient populations with specific presenting complaints (i.e. hip fractures, back pain, myocardial infarctions) or had no reporting on the presenting complaints. The CDC reported that the leading reasons for visiting the ED given by adults were gastrointestinal, cardiovascular and respiratory illnesses (Niska, Bhuiya & Xu, 2010).

Forty two percent of subjects that presented to the ED in this study were assigned a triage category of 2 (emergent), while fifty seven were assigned a 3, or urgent, category. These findings are consistent with Pines and Hollander’s (2008) study that reported 40% of their population was assigned a triage category of 2 and 38% were assigned triage level 3. But these results are not consistent with the CDC report by Niska, Bhuiya and Xu, (2010) that reported triage category 2 patients made up 11.3% and category 3 made up 38.5% of the total sample visits. However, the shortened length of stay for patients in triage category 1 and the exclusion of patients with triage categories 4 and 5 from this study may account for the discrepancy with previous studies.

Findings

This study examined four questions:

   RQ1. Was there an association between the length of time between vital signs recording and differing degrees of ED crowding?
RQ2. On days when the ED was crowded, what factors influenced the frequency with which emergency nurses monitor patients’ vital signs?

RQ3. What factors influenced the time to the emergency nurse’s initial response when abnormal vital signs were present?

RQ4. What effect did the degree of ED crowding have on the measurement of vital signs for a patient in the ED?

Research Question 1 Findings

The average time between vital signs overall was 125 minutes, 132 minutes for crowded periods and 103 minutes for noncrowded periods. This is consistent with previous research that reported similar delays in thrombolysis and pain medication administration during times of ED crowding (Pines & Hollander, 2008; Schull, et al, 2004). While there may be clinical importance with an increase of 30 minutes between vital sign records, this study did not examine outcomes. It may be that 2 hours between vital sign is a reasonable time period among patients with a triage category of 2 or 3 and an average MEWS score of 1 or 2.

The time increase between vital sign recordings was only 1.2 minutes per 1 point increase in the EDWIN score. In the study by Pines, Garson, et al (2008), ED crowding was associated with perceptions of care compromise. While the frequency of vital signs are not established as influencing care or perceptions of care, vital signs are one point of contact between ED nurses and ED patients. Previous research has demonstrated that the quality of patient care decreases when the ED becomes more crowded. Perhaps dividing the degree of crowding
into quartiles and re-examining the data would identify periods of higher associations with the time between vital signs.

Statistical findings from this study indicate that increased crowding and increased time between vital signs are associated. While the author's personal experience and anecdotal evidence indicates that a decrease of less than two minutes in the length of time between vital sign monitoring is unlikely to be clinically important except during cardiac arrest or similar life-threatening circumstances and interventions, the cumulative effect of increased crowding may have clinical importance. As crowding increases from 1 to 29 in the EDWIN scale, the time between vital sign records, according to data in the current project, could increase by over 30 minutes and that infrequency can result in a missed opportunity to capture clinically important changes. Thus, this study suggests the variation between noncrowded and severely crowded periods could have both statistical and clinical significance.

The average time between vital sign recording found in this study was consistent with previous research. Armstrong et al (2008) found that only 7% of patients had all vital signs repeated every 60 minutes. Currently there are no national standards for the frequency of vital sign monitoring among ED patients. Because there was only one study to compare these findings, more research should be performed in order to draw more accurate conclusions.

An unexpected finding of this study was that crowded periods had fewer missed vital signs than noncrowded periods. Nineteen percent of vital signs were missing during periods of noncrowding, while crowded periods had missing
values only 14% of the time. Temperature, pain and SpO2 were the most commonly missed vital signs during both crowded and noncrowded periods. The cause for this difference is not explained in the data collected for this study. But this does provide information about the types of information that is commonly missed in the ED. Likewise, the amount of missing values for vital signs was an important finding because such missed cues have been associated with failure to rescue among inpatient populations. It may be that examining missed vital signs rather than the time between vital signs is a more appropriate approach to evaluating quality of care.

Research Question 2 Findings

The analysis indicated that increased length of stay, increased age, and a decrease in triage category influenced the time between vital sign recording. Other predictor variables (i.e. number of comorbidities, the presence of abnormal vital signs, the number of prescription medications, and the number of routes of medication administration) also demonstrated relationships with the time between vital sign recordings. The structural equation model analysis showed that the length of stay and triage category did have an impact on the time between vital sign recordings while age did not.

The length of time between vitals increased with a longer length of stay. One would expect patients with deranged vital signs would be discharged from the ED into the hospital quicker. Thus, the increase time between vital signs may be explained by the likelihood that stable patients (i.e. patients with stable vital signs) remain in the ED either awaiting treatment or boarding while waiting for an
inpatient bed to become available. These results agree with previous research by Pines, Pabhu, Hilton, Hollander and Datner (2010) that demonstrated that length of stay and medication delays are both associated with ED crowding. Patients needing frequent vital signs (e.g. every 5 minutes) are usually discharged from the ED quickly and transported to surgery, the cardiac catheterization lab or an intensive care unit.

More research needs to be conducted to determine if an increase in the length of time between vital signs leads to adverse outcomes. One possible explanation was the presence of boarders being held in the ED. When a patient is admitted to a hospital that does not have an available inpatient bed, the patient is cared for in the ED. These patients may remain in the ED for hours or days (Gilligan, Winder, Singh, Gupta, Kelly et al, 2008). Experience revealed that often during the patient’s stay, the ED nurse follows inpatient floor protocol and obtains vital signs less frequently (e.g. every 4 hours) on stabilized inpatient boarders. Following these protocols may have influenced the findings of this study. While there were no outliers as determined by assumption testing, it may be that examining data by quartiles would better capture the influence that the monitoring of boarders’ vital signs had on the sample. Grouping those patients with the longest and shortest times between vital signs would better determine influential factors. Another explanation is that more acutely ill/injured patients are admitted or expire more quickly than patients that are stabilized. Further analysis is needed to explain this phenomenon.
No differences in the length of time between vital signs were identified based on age, gender, ethnicity, marital status, presence of family or type of insurance. Previous research on disparate treatment is mixed. Gardner, Almeida, Maselli and Auerbach (2010) report no difference in the treatment of elderly patients presenting to the ED with complaints of abdominal pain based on gender. Other studies report female patients presenting with acute abdominal pain receive less pain medications while females presenting with headache or neck pain receive a larger quantity and stronger dose of medication than their male counterparts (Chen, Shofer, Dean, Hollander, Baxt et al, 2008; Rafftery, Smith-Coggins, & Chen, 1995). There were no data about ethnicity, marital status or type of insurance in published reports related to disparate care in the ED. This project has provided unique information suggesting that vital sign monitoring is not based on common social indicators of poverty or support. The lack of findings related to disparate care should reassure the public in the setting of this study.

The length of time between vital signs increased with the following factors: less acute triage category, fewer routes of medication administered in the ED, reduced number of prescription medications and lower number of comorbidities. Patients had more frequent vital sign recordings when abnormal vital signs were recorded and as age increased. These are reasonable practices because less acutely ill patients do not require vital signs monitoring as frequently as patients with abnormal assessments. Elderly patients had more comorbidities. Because of the increased number of disorders, this population would have a reduced
physiological compensation to recover from the underlying problems that cause abnormal vital signs (Porter & Kaplan, 2010). There is no standard of care regarding minimal or maximal frequency of vital signs in the ED except for selected conditions such as stroke or angina (Broderick, Connolly, Feldman, Hanley, Kase, et al, 2007).

Triage category had the greatest impact on the time between vital signs. The Emergency Severity Index (ESI), used to assign triage category, is the most common triage system used in the United States and is endorsed by the Emergency Nurses Association and the Association of American College of Emergency Physicians. The ESI has been found to be both a valid and reliable instrument for determining patient acuity and resource use. Although the majority of patients in this study were assigned triage categories 2 or 3, the results agreed with previous studies that demonstrated that a more acute (lower triage category) patient required more resources as evidenced by more frequent vital signs. This study has found that for every increase of one in the triage category (becoming less acute) the time increased by 40 minutes. This is consistent with expected practice. It is reasonable to monitor the more acute patients’ vital signs more often. Because the shorter length of stay for the most critically ill patients (e.g. triage category 1) disqualified the subjects from inclusion in the study, it is not known if there is a difference between this population and the sample population.

Patients that received medications in the ED by a greater number of routes (i.e. po, iv, im) had a decrease in the average length of time between vital signs recordings. The decrease averaged 13 minutes (i.e., from 132 to 119
minutes). This finding indicates that when multiple routes are used to provide drugs, it became more likely that the nurse reassessed vital signs, a component of providing direct nursing care. Previous research has shown emergency nurses spend only 25.8% of the shift providing direct patient care (Hobgood, Villani, & Quattlebaum, 2005). Increasing the frequency of medication administration may increase the time the nurse is at the bedside while also providing an opportunity to collect a set of vital signs. Alternatively, more routes of medications may require a nurse to reassess vital signs to determine effects of drug-based interventions.

As the crowding level (EDWIN score) increased by one point the length of time between vital signs only increased by one minute. The results do not appear to have to have a substantial impact on the time between vital signs until the whole range of EDWIN scores are included. There was an increase of 28 points from the lowest to the highest EDWIN scores. This would account for an increase in the time between vital signs by 33 minutes because of crowding alone. One possible explanation for the small incremental change between each degree of crowding is teamwork among the ED staff. Previous research has shown that the level of teamwork among the nursing staff has impacted the extent of missed nursing care (Kalisch & Lee, 2010). One aspect of teamwork is communication. Is there better communication during times of crowding? Increased communication may lead to more efficient care of patients. The ED staff may pull together and work as a faster and more efficient team when the ED is crowded. Thus, while the change is incremental and may be significant over larger
variations in crowding, it is somewhat reassuring to know that only small, clinical changes occur with small changes in crowding levels.

This analysis showed patients that arrived in private cars had a greater length of time between vital sign recording. This is consistent with previous studies which show that more acutely sick or severely injured patients arrived by ambulance instead of private car (Ruger, Richter & Lewis, 2006). Finally, this is the first study to suggest that marital status or type of insurance do not contribute to disparate care.

**Research Question 3 Findings**

This research question could not be tested using the planned multiple regression analysis due to a small sample size. None of the variables had a significant relationship with the time from acknowledgement of the abnormal vital signs to a nurse’s reaction to abnormal vital signs. While analysis did not provide conclusive evidence, it is difficult to make a strong conclusion because of the small sample size and low power.

The small sample size occurred because 76 of the 121 charts that had abnormal vital signs did not have a documented intervention by the nursing staff. Although abnormal vital signs were present in the majority of subjects in this study, the abnormal vital signs were not extreme enough to drastically modify the MEWS value for most of the subjects. The lack of documented reaction by the emergency nurses to the deviation from normal vital sign parameters for these patients may be explained by unremarkable assessments by the nurse which warranted no needed reactions to the abnormality. However, this lack of reaction
may be due to a missed cue by the nurse. Unfortunately, the results of this study agrees with previous research that suggests that nurses did not initiate interventions nor notify proper personnel when physiological abnormalities, such as abnormal vital signs, were present (Schull, Ferris, Tu, Hux & Redelmeier, 2001; Cioffi, Salter, Wilkes, Vonu-Boriceanu, & Scott, 2006).

The definition used in this study for the nurse’s reaction to abnormal vital signs was purposefully made to be a broad interpretation of interventions by the nurse. Nurse reactions included such responses as medication administration as ordered by the physician, patient education, communication to physician, patient repositioning, reassessment or continued monitoring of the patient. Although communication was the most commonly documented intervention by the nursing staff, some instances of discussing condition changes may have been performed and not documented, exposing a limitation of a retrospective chart review. This lack of documentation may not have been an issue if the sample charts had been electronically based. Many Electronic Medical Record (EMR) systems require documentation whenever abnormal assessments are recorded in the chart. This requirement may have increased the amount of valid data points for this study. Future chart reviews performed on EMR data may assist in determining if the problem is missed documentation of responses to abnormal vital signs or lack of recognition by the nurse.

One possible explanation for the nonsignificant results may be explained by the study’s retrospective design. Because this was not a prospective observational study, the researcher could not record the actual time the nurse
observed the abnormal vital sign and compare it to the time of the reaction nor could the researcher verify that vital signs were transcribed accurately. As performed, the study was dependent on the completeness of the nurses’ charting. It may be that vital signs were monitored more frequently but not documented in the chart. Fatigue and stress have been linked to charting errors and omissions by nurses (Warren & Tart, 2008). Crowding may contribute to fatigue, stress and poor documentation; linking vital signs with patient outcomes or staff reactions are potential future investigations.

Additionally, the lack of recorded reactions to the abnormal vital signs may also be due to incomplete or incorrect charting. Practically, the nurse would not stop treating the patient to document an abnormal vital sign. Often vital signs and the reactions or treatments performed around the same time get documented after the intervention is complete and are assigned the same time in the chart. Additionally, if the vital sign was recorded incorrectly, the nurse may not have needed to intervene. Research has shown that vital signs are manually recorded incorrectly up to 10% of the time (Gearing, Olney, Davis, Lozano, Smith, & Friedman, 2006). Despite the small size and low power of this analysis, findings do support further investigation to evaluate this research question.

**Research Question 4 Findings**

Previous research has demonstrated that ED patients perceive that care is compromised during times of crowding (Pines, Garson et al, 2007). However, the findings from this study indicated that there was no change in the measurement of the subjects’ composite vital signs in the presence of ED crowding. The lack of
change in the MEWS scores may be explained by the missing temperature values. Often, temperature was not reassessed in this population unless it was the presenting complaint of the patient. Because a temperature value is required to calculate a MEWS value the previously recorded temperature score was substituted for missing temperature scores under the assumption that the ED nurse would have assumed the patient’s temperature was unchanged. That might explain the high correlation among the MEWS scores. The next most frequently missed vital sign was a pain assessment. When comparing the vital signs of patients during periods of crowding with those of the noncrowded population, heart rate, systolic blood pressure and respiratory rate were all higher in the crowded population. Heart rate and respiratory rate were the only vital signs that had a statistically significant difference in their values from triage to discharge. It may be that crowding does not affect patient vital signs. While vital signs may indicate stress, findings from this study do not suggest patients were stressed by ED crowding. An alternate explanation may be that vital signs may not be the best way to capture patient responses to crowding. It may be more beneficial to study if increased traffic in the ED or work pace of the nursing staff affects patients’ vital signs or explore more of the environmental influences on the patients’ physiological responses or the nurses’ reactions.

**Power**

Post hoc power analysis for each research question was performed for this study using G*Power3.0.10. Power analysis for Research Question 1, based on a sample size of 192 charts, a medium effect size, and an $\alpha$ of 0.05, was
calculated to be 0.92. This result promoted the conclusion that the probability of a Type II error was smaller than planned a priori.

Post hoc power analysis for Research Question 2 was calculated based on a sample size of 192 charts, a medium effect size ($f^2 = .15$), $\alpha$ of 0.05 and 14 predictor variables. Computed achieved power was 0.948. This value indicates that the probability that the conclusions from this question being a false negative was extremely unlikely.

Post hoc power for Research Question 3 was based on a sample size of 45 charts, a medium effect size, and an $\alpha$ of 0.05, was calculated to be 0.61. The nonsignificant correlation closest to being significant ($r = -.270$) was used in the calculation of power. The low power for this research question was due to the lower than expected sample size and indicated a greater chance of concluding there was no relationship between the variables when one may have been identified if the sample had been larger.

Post hoc power for Research Question 4 was based on sample size of 186 charts, alpha of .05 and 1 predictor (EDWIN score). Power was computed to be 0.9995. This means that the probability of incorrectly concluding that there is no relationship is remarkably small and verified that the non-significant relationship is accurate.

**Theoretical Framework**

The conceptual model for this study combined a modified version of Asplin’s Model of ED crowding with Donabedian’s Structure-Process-Outcome model to create a model that was used to explore the effects of ED crowding.
Asplin’s model shows the factors that create ED crowding. The modified model questioned whether nursing care was impacted by ED crowding (see Figure 10).

This study began by examining a portion of the model: (a) Input factors and (b) throughput factors as well as (c) nursing interventions that occur between these two factors. Input factors for this study included:

- Age
- Gender
- Ethnicity
- Marital Status
- Insurance Status
- Number of Comorbidities
- Number of Prescription Medications
- Number of Over-the-Counter Medications
- Mode of Arrival
- Family Presence
Throughput factors were:

- Total Length of Stay (minutes)
- Length of Time Between Vital Sign Recordings

Nursing interventions were:

- Triage Category
- Number of Routes of Medications Administered in the ED

The analysis showed that the length of time between vital signs was significantly influenced by the length of stay, number of routes of medications administered in the ED, EDWIN score, number of comorbidities, arrival in a private car and triage category. Triage category also had a significant influence on the EDWIN score. This association was expected because the triage category is used in the calculation of the EDWIN score. Although age, gender and the number of comorbidities were significant predictors of triage category, they did not significantly influence EDWIN scores or the length of time between vital signs. This may demonstrate the emergency nurse’s ability to prioritize care to the most acutely ill patients regardless of age, gender or previous medical history. Examining indicators of nursing performance has the potential to impact adverse outcomes of ED crowding and patient responses, while the factors that contribute to crowding are occurring. The results of this study lend support to the model proposed by this paper.
Strengths and Limitations

The most obvious limitation to this study was inherent to utilizing a retrospective chart review. By performing a chart review, the available data was limited to handwritten notations from the nursing staff. Because this study was performed before the implementation of computer charting, poor handwriting made data collection difficult and introduced the potential for transcription errors. However, only one person collected data from said charts and that person underwent training in the use of the pilot-tested data collection tools. Charts were selected from a single institution and therefore may reflect biases within this emergency department regarding what interventions should be performed by the nursing staff and when such interventions were appropriate. There were no particular indicators that this Magnet designated, academically centered ED varied in culture from other EDs. Most severe limitation is the dramatic difference between what is done and what is documented. It is unknown how frequently vital signs were taken and not recorded. The results of this study imply that vital signs were rarely missed, but the response to abnormal vital signs was missed. The discrepancy between nursing actions and nursing documentation has been identified as a problem among many EDs as well as a source of lost revenue (ED Management, 2002). It is imperative that nurses recognized abnormal vital signs and notify the emergency physician. Perhaps the hand-off of important patient assessments is the true failure point in providing high quality patient care.

Because the data being analyzed were not collected for the purpose of this study, some of the data were incomplete or measured using methods that
were not ideal for addressing the research questions of this study. This was most obvious in the calculation of the MEWS. Temperatures were often not measured with other repeated vital signs and responsiveness had to be deduced from available nursing notes and documented assessments. The pilot study that was performed in an effort to control for missing data helped guide decision rule establishment to deal with calculating the most accurate MEWS value possible. Most temperature values were normal (98%), so it was reasonable to use a normal baseline at subsequent time points.

Internal validity for this study does not appear to be subjected to a history threat (outside event that might have produced effects on the dependent variable). News reports from the Cleveland Plain Dealer front and metro pages were reviewed for reports of disasters on the days selected for study inclusion and did not reveal any mass causality, illness outbreak or other event. Such events may have significantly changed the crowding level of the ED, affected the staff to patient ratios or the patient acuity trends in the ED during the sampling time. No internal factors, such as a change in protocol or short staffing, were identified during these times that would have affected the amount of time required to initiate interventions.

Selection bias, a threat to internal validity that can occur when nonrandom procedures are used to assign subjects to conditions or when random assignment fails to balance differences among subjects, was controlled for by consistently measuring variables in all patients seen in the ED. Addressing the variability that affected the rate of the ED staff’s response (e.g. differing acuity
levels in patients) assisted in decreasing the effect of selection bias in the study sample. Utilizing this method also aided in decreasing threats to external validity, such as the interaction of selection bias and the research variables (Campbell & Stanley, 1963).

Potential confounders to this study are numerous. However, because this was a retrospective chart audit and observations were not obtained as they occurred, that was expected. To help account for this, charts with incomplete triage data were excluded from the analysis. However, staff behaviors, nurse to patient ratios, level of education and certifications of nurses, and the use of non-nursing personnel during crowded or noncrowded times may have contributed to the missing data thereby compromising the results. Perhaps examining staffing levels instead of crowding levels would have provided more dynamic effects on the time between vital signs. It should be noted that no information was collected on the behaviors of the staff in the department. Additional data on staff behavior may be pertinent as there may be comradery of staff resulting in the staff/team working better together when crowding was present than when the ED was not busy (Kalisch & Lee, 2010).

Little is known regarding work pace in the ED, especially during times of crowding. It is possible that there is a biphasic response to ED crowding that was not explored. It is possible that the length of time between vital signs is longer when there are very few patients in the ED. Staff may take this time to do other tasks such as stocking rooms, organizing supplies and socialize with coworkers and do not focus on patient care when the work pace is slow. Similarly, the time
between vitals would be longer when the pace in the ED is fast. The more stable patients may not have their vital signs assessed as frequently during the times when the ED is overwhelmed. It seems likely that there may be a pace between the slow and busy times when the staff and processes work best.

Research question 3 has limited generalizable results because of the small sample size. The small sample size led to low power and a greater possibility of having a false negative result. The small sample size may have been due to nurses relying on the whole patient assessment rather than the abnormal vital signs.

The generalizability of this study is limited. This study was conducted at a single academic urban Emergency Department and only included adult patients. The results of this study cannot be assumed for other populations, (e.g. pediatric) at other settings including rural or community hospital EDs. The results of this study could not be generalized to patients assigned a triage category of level 1 because only one patient with this category was included in this study. The purpose of this study was not to establish generalizable results but to test the model and examine influential factors for future studies. So despite its limitations, findings of this study are reasonable to use in future studies of EDs and emergency populations with characteristics similar to those reported herein.

This study was the first to use Structural Equation Modeling (SEM) to explore patient care in the ED. This analysis allowed for examination of the multiple factors that affect vital sign recording in the ED. SEM adds data driven information about the contextual factors nurses use in the ED setting. This is
congruent with reports that suggest nursing practice and education benefits from situational and holistic information rather than an isolated vital sign or even composite score based on heart rate, blood pressure, respiratory rate, and oxygen saturation (Parse, 1999). The use of SEM provided a unique scrutiny of the interrelationship of variables that affect the time between vital signs.

With the limited research available on the frequency of vital signs in the ED, this study identified potential areas of concern that need further examination and may be improved with creative interventions. This study also helped to establish standards of practice for the frequency of monitoring vital signs in the ED related to triage level. Unwritten policies exist within EDs, but it is unclear if these policies are adequate or if they need to be amended. The undertaking of this study was needed to provide a foundation for future research that may identify strengths and weaknesses of care for patients in the ED during crowding. By identifying these actions, interventions can be designed and implemented that may decrease the adverse outcomes that have been correlated to ED crowding.

**Implications for Practice**

The goal of this study was to examine how ED crowding affects how the nurses care for patients and to see if crowding affects the patient’s physiology. The findings of this study provide the groundwork for future studies and demonstrate a need to better understand how the crowded ED environment affects the quality of patient care. The small sample size for Research Question 3 occurred because 76 of the 121 charts that had abnormal vital signs did not have a documented intervention by the nursing staff. This agrees with previous
research that suggests that nurses did not initiate interventions or notify proper personnel when physiological abnormalities, such as abnormal vital signs, were present (Schull, Ferris, Tu, Hux & Redelmeier, 2001; Cioffi, Salter, Wilkes, Vono-Boriceanu, & Scott, 2006). More analysis on the reasons why emergency nurses do not initiate interventions needs to be gathered so that appropriate education can be provided. The addition of nurse practitioners in the ED may help to improve outcomes for patients while increasing the education of the ED staff.

**Future Research**

This study has shown that crowding has a significant effect on the length of time between vital signs. If crowding affects this aspect of patient care, the next logical question is what other nurse-sensitive indicators are affected during periods of crowding? Additionally, how can nurses intervene to correct deviations from acceptable care when they occur? What does ED crowding mean to the patient in the ED? These are just some of the questions generated by the results of this study. In order to further explore this area, prospective studies using observers to capture the real-time responses of patients to various crowding conditions and the reactions of nurses should be performed, exploring linkages to outcomes and further testing the conceptual model developed for the current study. Similarly, the stress response of patients during ED crowding as well as the effect of crowding on patients' vital sign trends for the duration of their ED stay needs to be assessed to determine if patient outcomes are influenced by the presence of ED crowding and not only by the care provided to them during these times.
This study has demonstrated that nurses at the subject ED are successfully caring for patients when crowding is present. Proper prioritization may have had an impact in these results. It is not known if being assigned a lower triage category, effectively making the patient a lower priority, puts people at increased risk for lower quality of care during periods of crowding.

This study demonstrated a lack of findings related to disparate care. However, data was not collected to differentiate nursing home patients and patients arriving from the community. Determining if care is disparate based upon nursing home residency may help in determining the best methods for caring for patients.

Although the sample size was too small to determine what factors affect the nurse’s reaction time when abnormal vital signs were present, the fact that the sample size was too small indicates that more research is needed to determine why 76 of the 121 charts with abnormal vital signs had no interventions documented in the chart. Conducting a focus group of emergency nurses may provide important information in the exploration of this phenomenon. Identifying causes for the lack of response would help guide quality improvement initiatives and may decrease failure to rescue rates.

Reorganizing the sample population might help to explore other distinctive happenings that occurred during the study period. Examining the sample charts by quartiles, longest verses shortest length of stay, would account for the impact of patients being boarded in the ED on the time between vital sign recordings and might better determine influential factors. Regrouping the population of this
study by the crowding level at the time of the patient’s arrival would capture the initial care of patients before they were stabilized and identify potential areas of improvement and intervention.

Quality improvement projects in the ED have been undertaken in both the community and national settings. Nurses and physicians are working together to improve patient outcomes and to maintain improvements that have been gain from previous quality improvement projects. This study has contributed to the body of knowledge that exists that demonstrates that ED crowding has an adverse effect on patient care. Future studies can use the results of this research to determine the impact of ED crowding on patients and to formulate interventions through medical and nursing interventions, and administrative policies to positively affect outcomes.

Conclusion

The retrospective design of this study was chosen because it would provide a large amount of data and Level 4 evidence for establishing common practices regarding vital sign frequency. This non-experimental design was used to identify important variables and determine their relationships. It also provided a foundation on which future research can be based to evaluate nursing care during times of crowding in the ED. By assessing the quality of care provided to patients during periods of crowding, nurses can better understand the needs of these patients and develop interventions to counteract deviations from safe patient care that may be identified.
Vital signs have been considered an integral part of the nursing assessment and often used as a decision-making tool (Gilboy, Travers & Wuerz, 2000). Numerous studies have provided results that have validated the predictive power of the presence of abnormal vital signs and the clinical importance of properly monitoring and recording vital signs. Additionally, several studies have identified relationships between abnormal vital signs and patient deterioration and the need for life-saving interventions (Goldhill, White, & Sumner, 1999; Tarassenko, Hann & Young, 2007). While the length of time between vital signs was significantly different between periods of crowding and noncrowding, the time period of 1 minute is unlikely to affect clinical practice or patient outcomes. However, the cumulative effect of crowding on the time between vital signs may affect patient outcomes. The length of time between vital signs was significantly influenced by the length of stay, number of routes of medications administered in the ED, EDWIN score, number of comorbidities, arrival in a private car and triage category. It is only the second study to report typical frequency of vital signs in the ED among triage level 3 and 4 patients.

The conclusions that can be drawn from this study are:

1. As crowding increased the time between vital signs increased significantly but the clinical importance of this finding need further investigation.

2. Several factors contributed to the length of time between vital sign recordings. Length of stay in the ED, triage category and patients arriving in a private car had the greatest predictive value.
3. Reactions to abnormal vital signs were not commonly documented by nursing in the handwritten records used for this project.

4. Emergency department crowding did not have an effect on the MEWS value of patients but did correlate with an elevation in heart rate and respiratory rate.

These findings indicated that the conceptual model used for this study provided reasonable guidance to evaluate quality of care in the ED. These findings also suggested that the nurses at this Emergency Department provided consistent quality of care as measured by vital sign frequency, even during periods of crowding. High quality of care is mandated by the public as well as certifying agencies, and was noted in this study as disparate care in terms of social or socioeconomic factors was not detected. More information is needed to determine if frequency of vital signs surveillance contributes to high quality care. Results from this study may contribute to establishing a standard of care related to frequency of vital signs monitoring. Findings also provide direction for future research linking quality of care to missing vital signs or inadequate monitoring and ED team response to abnormal vital signs. There are limited data about the quality of nursing care in the ED and this project provided important baseline data about typical frequency of vital signs monitoring and factors that influenced the frequency of vital sign records. Providing high quality care implies that nurses need to ensure that standards of care are maintained for all patient populations regardless of the environment or circumstances. Understanding factors that
influence care and maintain optimal care in suboptimal circumstances like ED crowding is important to practice, education and research.
Appendix 1. ESI Triage Algorithm

1. Does the patient require immediate life-saving intervention?
   - yes → 1
   - no → B

2. Is the situation high risk or does the patient have signs of confusion, lethargy, disorientation, or severe pain/distress?
   - yes → D
   - no → C

3. How many different resources are needed?
   - none → 3
   - one → 4
   - many → 5

4. Danger zone vitals?
   - Consider if the patient meets any of the following criteria:
     - HR: <3 m/180, >50
     - RR: <3 m/160, >40
     - <3 y: >140, >30
     - >8y: >100, >20
     - SaO2: <92%
   - no → 3

5. Proceed with immediate intervention.
Appendix 2. Results of testing the primary and secondary assumption of regression for Research Question 1.

RQ1 Descriptives:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (s.d.)</th>
<th>Skewness (s.e.)</th>
<th>Kurtosis (s.e.)</th>
<th>n (missing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>125.52 (92.59)</td>
<td>2.939 (.175)</td>
<td>15.452 (.349)</td>
<td>192 (14)</td>
</tr>
<tr>
<td>EDWIN</td>
<td>10.464 (9.996)</td>
<td>.871 (.170)</td>
<td>-.857 (.339)</td>
<td>204 (2)</td>
</tr>
<tr>
<td>Crowded?</td>
<td>.75 (.432)</td>
<td>-1.148 (.169)</td>
<td>-.688 (.337)</td>
<td>206 (0)</td>
</tr>
</tbody>
</table>

Residuals Statistics

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahal. Distance</td>
<td>.000</td>
<td>3.687</td>
<td>.995</td>
<td>1.079</td>
<td>192</td>
</tr>
<tr>
<td>Cook's Distance</td>
<td>.000</td>
<td>.251</td>
<td>.005</td>
<td>.021</td>
<td>192</td>
</tr>
<tr>
<td>Centered Leverage Value</td>
<td>.000</td>
<td>.019</td>
<td>.005</td>
<td>.006</td>
<td>192</td>
</tr>
</tbody>
</table>

a. Dependent Variable: Frequency of vital sign recording
Appendix 3 Results of primary and secondary assumptions of regression for Research Question 2

<table>
<thead>
<tr>
<th></th>
<th>N (missing)</th>
<th>Mean (s.d.)</th>
<th>Std. Dev</th>
<th>Skews (s.e.)</th>
<th>Kurtosis (s.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Rx meds</td>
<td>144(8)</td>
<td>3.31(3.11)</td>
<td>3.105</td>
<td>.925(.202)</td>
<td>.220(.401)</td>
</tr>
<tr>
<td>Age</td>
<td>150(2)</td>
<td>47.25(21.6)</td>
<td>21.59</td>
<td>.401(.198)</td>
<td>-.822(.394)</td>
</tr>
<tr>
<td># commorbid</td>
<td>149(3)</td>
<td>2.60(1.91)</td>
<td>1.910</td>
<td>.645(.199)</td>
<td>-.003(.395)</td>
</tr>
<tr>
<td>family present</td>
<td>150(2)</td>
<td>1.61(.504)</td>
<td>.504</td>
<td>-.281(.198)</td>
<td>-1.538(.394)</td>
</tr>
<tr>
<td>Gender</td>
<td>150(2)</td>
<td>.28(.451)</td>
<td>.451</td>
<td>.990(.198)</td>
<td>-1.034(.394)</td>
</tr>
<tr>
<td>Married</td>
<td>148(4)</td>
<td>.22(.413)</td>
<td>.413</td>
<td>1.393(.199)</td>
<td>-.061(.396)</td>
</tr>
<tr>
<td>insurance</td>
<td>149(3)</td>
<td>.25(.433)</td>
<td>.433</td>
<td>1.177(.199)</td>
<td>-.623(.395)</td>
</tr>
<tr>
<td>African Am</td>
<td>149(3)</td>
<td>.79(.412)</td>
<td>.412</td>
<td>-1.403(.199)</td>
<td>-.031(.395)</td>
</tr>
<tr>
<td>Private car</td>
<td>149(3)</td>
<td>.67(.471)</td>
<td>.471</td>
<td>-.736(.199)</td>
<td>-1.478(.395)</td>
</tr>
<tr>
<td># routes meds administered</td>
<td>148(4)</td>
<td>1.76(1.12)</td>
<td>1.121</td>
<td>.333(.199)</td>
<td>.128(.396)</td>
</tr>
<tr>
<td>Number of OTC meds</td>
<td>145(7)</td>
<td>.61(1.03)</td>
<td>1.029</td>
<td>2.129(.201)</td>
<td>4.883(.400)</td>
</tr>
<tr>
<td>LOS (mins)</td>
<td>148(4)</td>
<td>424.36(221)</td>
<td>220.97</td>
<td>1.969(.199)</td>
<td>5.671(.396)</td>
</tr>
<tr>
<td>Triage Category</td>
<td>152(0)</td>
<td>2.56(497)</td>
<td>.497</td>
<td>-.265(.0195)</td>
<td>-1.956(.398)</td>
</tr>
<tr>
<td>Triage vitals</td>
<td>144(8)</td>
<td>2.3333(1.93)</td>
<td>1.932</td>
<td>2.459(.202)</td>
<td>7.623(.401)</td>
</tr>
<tr>
<td>Time between vital signs</td>
<td>144(8)</td>
<td>132.749(100)</td>
<td>100.142</td>
<td>2.863(.202)</td>
<td>14.13(.401)</td>
</tr>
</tbody>
</table>

### Influential case

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahal. Distance</td>
<td>5.352</td>
<td>54.434</td>
<td>14.891</td>
<td>6.869</td>
</tr>
<tr>
<td>Cook's Distance</td>
<td>.000</td>
<td>.583</td>
<td>.010</td>
<td>.051</td>
</tr>
</tbody>
</table>

a. Dependent Variable: Frequency of vital sign recording

### Linearity

![Partial Regression Plot](image1)

![Partial Regression Plot](image2)
Constant error variance

<table>
<thead>
<tr>
<th>Variable</th>
<th>N (missing)</th>
<th>Mean (s.d.)</th>
<th>Median (Mode)</th>
<th>Skewness (s.e.)</th>
<th>Kurtosis (s.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studentized Deleted Residual</td>
<td>137 (69)</td>
<td>.0166 (1.12)</td>
<td>-.230 (-.480)</td>
<td>3.752 (.207)</td>
<td>25.6 (.411)</td>
</tr>
</tbody>
</table>
Appendix 4. Transformation for Research Question 2: Linearity of Age variable

### Statistics

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>age squared</th>
<th>age cubed</th>
</tr>
</thead>
<tbody>
<tr>
<td>N Valid</td>
<td>202</td>
<td>202</td>
<td>202</td>
</tr>
<tr>
<td>Missing</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Mean</td>
<td>47.58</td>
<td>2723.5396</td>
<td>177326.2822</td>
</tr>
<tr>
<td>Median</td>
<td>47.50</td>
<td>2256.5000</td>
<td>107207.5000</td>
</tr>
<tr>
<td>Mode</td>
<td>18(^a)</td>
<td>324.00</td>
<td>5832.00 (^a)</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>21.495</td>
<td>2280.85103</td>
<td>2.08751E5</td>
</tr>
<tr>
<td>Variance</td>
<td>462.046</td>
<td>5202281.414</td>
<td>4.358E10</td>
</tr>
<tr>
<td>Skewness</td>
<td>.408</td>
<td>1.053</td>
<td>1.578</td>
</tr>
<tr>
<td>Std. Error of Skewness</td>
<td>.171</td>
<td>.171</td>
<td>.171</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-.791</td>
<td>.247</td>
<td>1.633</td>
</tr>
<tr>
<td>Std. Error of Kurtosis</td>
<td>.341</td>
<td>.341</td>
<td>.341</td>
</tr>
<tr>
<td>Minimum</td>
<td>17</td>
<td>289.00</td>
<td>4913.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>94</td>
<td>8836.00</td>
<td>830584.00</td>
</tr>
</tbody>
</table>

\(^a\) Multiple modes exist. The smallest value is shown.

### Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Squar e</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>Change Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R Square Change</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F Change</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>df1</td>
</tr>
<tr>
<td>Original</td>
<td>.511(^a)</td>
<td>.261</td>
<td>.169</td>
<td>92.687</td>
<td>.261</td>
</tr>
<tr>
<td>Age squared</td>
<td>.518(^b)</td>
<td>.269</td>
<td>.171</td>
<td>92.595</td>
<td>.008</td>
</tr>
<tr>
<td>Age cubed</td>
<td>.521(^c)</td>
<td>.271</td>
<td>.167</td>
<td>92.812</td>
<td>.003</td>
</tr>
<tr>
<td>Age minus 16 squared</td>
<td>.518(^b)</td>
<td>.269</td>
<td>.171</td>
<td>92.595</td>
<td>.008</td>
</tr>
<tr>
<td>Age minus 16 cubed</td>
<td>.521(^c)</td>
<td>.271</td>
<td>.167</td>
<td>92.812</td>
<td>.003</td>
</tr>
</tbody>
</table>
Appendix 5. Results of Transformation to Improve Linearity of OTC Variable for Research Question 2

### Statistics

<table>
<thead>
<tr>
<th></th>
<th>Number of OTC meds</th>
<th>OTC square root</th>
</tr>
</thead>
<tbody>
<tr>
<td>N Valid</td>
<td>145</td>
<td>145</td>
</tr>
<tr>
<td>Missing</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Mean</td>
<td>.61</td>
<td>.4490</td>
</tr>
<tr>
<td>Median</td>
<td>.00</td>
<td>.0000</td>
</tr>
<tr>
<td>Mode</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>1.029</td>
<td>.63884</td>
</tr>
<tr>
<td>Variance</td>
<td>1.060</td>
<td>.408</td>
</tr>
<tr>
<td>Skewness</td>
<td>2.129</td>
<td>.999</td>
</tr>
<tr>
<td>Std. Error of Skewness</td>
<td>.201</td>
<td>.201</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>4.883</td>
<td>-.344</td>
</tr>
<tr>
<td>Std. Error of Kurtosis</td>
<td>.400</td>
<td>.400</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>5</td>
<td>2.24</td>
</tr>
</tbody>
</table>

### Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>R Square Change</th>
<th>F Change</th>
<th>df1</th>
<th>df2</th>
<th>Sig. F Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>.511a</td>
<td>.261</td>
<td>.169</td>
<td>92.687</td>
<td>.261</td>
<td>2.849</td>
<td>15</td>
<td>121</td>
<td>.001</td>
</tr>
<tr>
<td>OTC sq root</td>
<td>.514b</td>
<td>.264</td>
<td>.166</td>
<td>92.872</td>
<td>.003</td>
<td>.518</td>
<td>1</td>
<td>120</td>
<td>.473</td>
</tr>
</tbody>
</table>

Partial Regression Plot

Dependent Variable: Frequency of vital sign recording
Appendix 6. Results of Transformation to Improve Linearity of Med Route Variable for Research Question 2

### Statistics

<table>
<thead>
<tr>
<th></th>
<th>number of routes medications administered</th>
<th>Routes square root</th>
</tr>
</thead>
<tbody>
<tr>
<td>N Valid</td>
<td>148</td>
<td>148</td>
</tr>
<tr>
<td>Missing</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Mean</td>
<td>1.76</td>
<td>1.1998</td>
</tr>
<tr>
<td>Median</td>
<td>2.00</td>
<td>1.4142</td>
</tr>
<tr>
<td>Mode</td>
<td>2</td>
<td>1.41</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>1.121</td>
<td>.57110</td>
</tr>
<tr>
<td>Variance</td>
<td>1.257</td>
<td>.326</td>
</tr>
<tr>
<td>Skewness</td>
<td>.333</td>
<td>-.979</td>
</tr>
<tr>
<td>Std. Error of Skewness</td>
<td>.199</td>
<td>.199</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>.128</td>
<td>.338</td>
</tr>
<tr>
<td>Std. Error of Kurtosis</td>
<td>.396</td>
<td>.396</td>
</tr>
<tr>
<td>Minimum</td>
<td>0</td>
<td>.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>5</td>
<td>2.24</td>
</tr>
</tbody>
</table>

### Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>R Square Change</th>
<th>F Change</th>
<th>df1</th>
<th>df2</th>
<th>Sig. F Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>.511a</td>
<td>.261</td>
<td>.169</td>
<td>92.687</td>
<td>.261</td>
<td>2.849</td>
<td>15</td>
<td>121</td>
<td>.001</td>
</tr>
<tr>
<td>Routes sq root</td>
<td>.512b</td>
<td>.262</td>
<td>.164</td>
<td>93.003</td>
<td>.001</td>
<td>.179</td>
<td>1</td>
<td>120</td>
<td>.673</td>
</tr>
</tbody>
</table>
Appendix 7. Data collection tool

Subject ID #_____

___ Age

___ Gender (0=female, 1= male)

___ Payment method (1= self pay, 2= private insurance, 3= Medicare, 4= Medicaid, 5= other)

___ Ethnicity (0= Caucasian, 1= African American, 2= Asian, 3= Hispanic, 4= Other)

_________Date of arrival

________Time of arrival

___ Mode of arrival (0= private car, 1= ambulance, 2= police, 3= other)

___ Triage category (1-5) ___

___ Comorbidities (1=yes, 2=no)

    (if yes, list)_____________________________________

___ Has HIV status been assessed? (1=yes, 2= no)

___ Family present (1=yes, 2= no)

    (if yes, what relationship?) _____

Presenting complaint ______________________________

Medications reported taken by patient at home

_________________________________________

_________________________________________

________

Is patient currently following a medical regimen (compliance with meds)?

___________________

___ Triage T
Subject ID #______

____  Triage HR
____  Triage RR
____  Triage BP
____  Triage SP02
____  Triage Pain

____ Time patient seen by MD

____ Time MD posts disposition

____ Were Vitals repeated? (1=yes, 2=no)

____ Time of first repeated vitals
____ First repeated T
____ First repeated HR
____ First repeated RR
____ First repeated BP
____ First repeated SP02
____ First repeated Pain

List all times of vital sign recordings 1)______ 2)______ 3)______ 4)______ 5)______

6)______ 7)______ 8)______ 9)______ 10)______

____ Abnormal vitals present? (1=yes, 2=no)

____ Abnormal vitals identified? (1=yes, 2=no)

____ Was there follow up on abnormal vital signs? (1=yes, 2=no)

    if yes, what time was intervention?____
    if yes, describe intervention__________________________
Subject ID #_____

______D/C time

Discharge diagnosis ________________________________

___ Disposition (0=death, 1=home, 2=med/surg 3=cardiac, 4=MICU/SICU, 5=OR, 6=transfer)

______D/C T

______D/C HR

______D/C RR

______D/C BP

______D/C SP02

______D/C Pain

Interventions ___________________________________________________________

Route of medications administered in ED (1=PO, 2=SQ, 3=IM, 4=IVP, 5=IVP, 6=IO 7=other)

________________________

Medications received in ED

1_____________________

2_____________________

3_____________________

4_____________________

______Blood products in ED (1=yes, 2=no)

_____ Readmits 24-48hrs? (1=yes, 2=no)

(if yes, dx?) ________________________________
References


(2002). Are you losing $250,000 of revenue each year? *ED Management, 14*(12), 139-41.


arrests and intensive care utilisation in acute Medical admissions. *Anesthesia, 58*(8), 797-802.


