Improving the Supply Process in an Interventional Procedures Unit

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Megan M. Rose

Kirkhof College of Nursing

Grand Valley State University

Advisor: Rebecca Davis

Project team Member: Sylvia Simons

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Table of Contents

CHAPTER

1 INTRODUCTION AND BACKGROUND........................................ 5
   Microsystem Assessment................................................. 5
   Supply Chain Process.................................................. 7
   Proposed Evidence Based Project...................................... 9
   Evidence Based Support............................................... 10
   Conclusion...................................................................... 11

2 LITERATURE REVIEW....................................................... 12
   Methods........................................................................... 13
   Current Status of the Healthcare Supply Chain.................... 14
   Application of Lean Interventions.................................... 15
   Sustainability of Interventions........................................ 17
   Conclusion...................................................................... 19

3 THEORETICAL FRAMEWORK............................................... 21
   Definition of the Framework........................................... 21
   DMAIC Model.................................................................... 22
   Conclusion...................................................................... 27

4 CLINICAL PROTOCOL....................................................... 28
   Pre-Implementation Protocol Steps.................................... 28
   The Improvement Phase.................................................. 29
   The Control Phase......................................................... 31
   Cost Benefit Analysis..................................................... 32
   Potential Challenges...................................................... 35
   Conclusion...................................................................... 35

5 PROTOCOL EVALUATION.................................................. 37
   Evaluation of Protocol.................................................... 37
   Strengths of the Protocol................................................ 38
   Weakness of the Protocol............................................... 39
   Evaluation of Outcomes.................................................. 40
   Implications for Practice............................................... 42
   Project Limitations....................................................... 42
   MSN Essentials............................................................ 43
   Conclusion...................................................................... 44
Abstract

In the combined cardiac catheterization and interventional radiology unit of an urban Midwestern hospital, having supplies when and where they are needed is necessary for efficiently and safely completing a wide variety of procedures. Due to the complexity of the supply chain process in this setting, baseline data collection revealed many missing supplies, overnight shipments, and expired items. In this project, the MSN student sought to determine whether a Clinical Nurse Leader driven Lean Six Sigma based approach to supply chain interventions in the interventional procedures setting would improve outcomes and lead to financial savings by decreasing waste and variation. The DMAIC model was used as a framework for the project and a three phase Kaizen improvement project was developed with the final stage being implementation of a two-bin (kanban) supply storage and ordering system. This paper will provide an introduction to the clinical microsystem, a literature review of evidence regarding the proposed intervention, a description of the DMAIC framework, an outline of the clinical protocol, and a final evaluation of its implementation. While installation of the two-bin system is currently awaiting funding approval, analysis of changes made in preparation thus far include a decrease in the number of items missing each morning, a decrease in number of overnight shipments, and a decrease in expired items. Significant financial savings have also been achieved, which will be discussed. Moving forward, Lean Six Sigma is a promising approach to attaining further sustainable improvements in the supply process. The Clinical Nurse Leader is in an optimal position to combine knowledge of healthcare processes and team management skills to continue implementation of the proposed intervention.
Chapter 1: Introduction and Background

Availability of supplies when and where they are needed is vital to efficient and safe patient care in any clinical setting. In an urban Midwestern hospital's combined heart catheterization and interventional radiology department, the supply chain process has historically been a source of frustration due to the variation in ways products are ordered, delivered, tracked, and dispensed in the unit. The unit's Clinical Nurse Leader along with central supply dispatch leadership began efforts on a three phase supply chain intervention during fall 2016, which has already led to improvements in the daily struggles with inaccurate supply counts and missing items. This evidence-based protocol will outline a project to introduce and evaluate implementation of a two-bin (kanban) supply ordering and stocking system in the department's four procedure rooms with the goal to continue improving supply chain quality metrics and patient safety in the unit.

This introductory chapter will include a brief assessment of the clinical microsystem in which the project will take place and a description of how the stated problem currently impacts the microsystem. This will be followed by an introduction to the planned intervention to improve the current supply chain process and the evidence-based literature supporting the proposed change.

Microsystem Assessment

A clinical microsystem is defined as the "group of people who work together in a defined setting on a regular basis to create care for discrete subpopulations of patients" (Nelson, Batalden, Godfrey & Lazar, 2011, p. 3-4) and sustain their own clinical and business goals, processes, and technology to meet clinical outcomes (Nelson et al., 2011). The unit in which the proposed evidence-based protocol project will take place fully encompasses the definition of a
microsystem, aiming to provide a continuum of heart and vascular care ranging from prevention and diagnosis to treatment and recovery.

The combination cardiac catheterization lab and interventional radiology department differs from the typical clinical microsystem in that patient care in the unit centers around completion of procedures as opposed to inpatient acute care. Patients come to the unit for a wide variety of procedures such as cardiac catheterization, pacemaker placement, cerebrovascular accident intervention, peripherally inserted central catheter placement, subcutaneous port insertion, drainage tube checks, and arteriovenous fistulagram, among many others. On average, the department performs 10-20 scheduled procedures each weekday, totaling approximately 400 per month. The number of emergent cases varies, but requires staff to be on call at all times during off hours. Patients generally spend about 6 hours in the department including prep time, procedure, and recovery.

The department is highly specialized and relies on experienced registered nurses (RNs) and radiology technologists who meet specific qualifications for hire. Primary duties of RNs include close patient monitoring and assessment, medication administration (including moderate sedation), and ensuring complete and accurate documentation. Radiology technologists, who have a 2-4 year degree in radiology, are certified to administer radiation treatment and perform various diagnostic imaging. Primary duties include setting up supplies for procedures, operating equipment, and directly assisting the physician or physician's assistant (PA) during procedures. Three of these technologists are cardiovascular interventional specialists who have additional training in cardiac procedures.

A significant strength of the microsystem is a positive working relationship among the staff as a whole. The staff are comfortable with each other and have cultivated an environment
where they hold each other accountable, contributing to a culture of safety. Recent Culture of Safety and Engagement (COSE) survey results report one hundred percent of respondents feel like the unit works well together and 97% like the work they do. This is vital to staff buy-in and participation in quality improvement projects.

Many processes are essential to daily operation of the microsystem, each of which play a role in the microsystem’s goal to provide specialized quality care and positive procedural outcomes. Microsystem specific processes include patient scheduling, nursing handoffs, moderate sedation, procedure room turnover, a modified patient discharge, and the supply chain management process. Leadership and staff work continuously to ensure these processes run as effectively as possible, integrating changes as needed to maintain patient safety.

**Supply Chain Process**

The cardiac catheterization and interventional radiology department supply chain contains over 2700 separate items, many of which are used for high risk procedures. Supply management is therefore a daily necessity for the department. Prior to fall 2016, a department based supply technician oversaw all aspects of ordering and maintaining supplies; however, staff regularly expressed concerns with missing supplies posing a major safety risk to patients. As a prime example, a patient was scheduled for a liver biopsy requiring the use of a specialized catheter to perform the procedure. While setting up for the procedure, staff realized the needed catheter was out of stock and were forced to travel to a neighboring hospital for the item, delaying the procedure by two hours. Fortunately this was a routine procedure, but illustrates the potential for safety concerns and patient satisfaction fallouts related to supplies. Similarly, waste and workarounds in the supply chain system were leading to unnecessary costs including frequent overnight shipments, expired supplies remaining on the shelf, and a considerable
amount of time spent by department leadership troubleshooting discrepancies in the supply process.

The previous process for supplies was essentially on a one-for-one system dependent on the department supply tech as many supplies are ordered through specific routes including consignment, trunk order, or special order instead of coming from the hospital's central supply dispatch. As previously mentioned, in fall 2016, the department's Clinical Nurse Leader (CNL) and central supply dispatch leadership began a three-phase Kaizen (Lean-based) project to improve the supply chain process. The department based supply technician position was phased out and 0.25 of the FTEs were transferred to a dispatch based supply tech who now spends up to 2 hours per day in the department. Until January 2017, the CNL managed all special order items during the day; she then oversaw transition of this to the new dispatch based supply tech. This process consumed two to three hours of the CNL’s time each day, detracting from other job duties. A second major change in September 2016 included labeling all supplies with one of four colored stickers to symbolize the route for ordering the supply. Currently, a central supply dispatch staff member checks par levels, orders, and restocks centrally stored items each night with the goal of having all procedure rooms fully stocked by morning.

Baseline data collection in September 2016 revealed over 100 items missing or critically low prior to the start of procedures in the morning. The average number of overnight shipments per month from April to September 2016 was between 7 and 8, but as high as 14. Department records also show 33 expired products on the shelf in September 2016 at the start of any interventions.
Proposed Evidence Based Project

The supply chain process is complex and additional changes will be aimed at furthering improvements already initiated. The next phase of changes entails a two-bin (kanban) system implemented in all four department procedure rooms. This two-bin system devotes two appropriately sized bins to each supply within the supply cabinet, with supplies stocked according to expiration date, allowing those that have been in stock the longest to be used first. When the first of the two bins is empty, this bin is set aside to a designated area, refilled by central supply staff, and placed back in the cabinet behind the second bin. This process is simple and highly visual, facilitating ease of use for staff and contributing to improved supply chain outcomes.

This project will take place between January and August 2017, with official implementation of the two-bin system planned for April or May 2017. As will be further explored later, the supply chain process change project is based on Lean Six Sigma methodology, which aims to decrease waste and variation in the supply chain process (Smith, 2003). The first step to implement the project will be to solidify a plan and determine an official timeline for the intervention. To do this, consistent collaboration between the Master of Science in Nursing (MSN) student, CNL, and central supply dispatch leadership is essential. The intervention phase will involve the MSN student, CNL, supply staff, and nurses and techs from the unit to reorganize the procedure room supplies into the two-bin system. The staff must be educated about the new system before, during, and after this phase. This education will likely include the CNL and MSN student spending a significant amount of time doing face-to-face education and walking through the process with staff. The CNL will need to maintain open communication for any feedback about the system change. Once the two-bin supply system has
been initiated, evaluation of the process changes will continue based on supply chain quality metrics data: frequency and cost of overnight shipments, number of items missing or critically low in the morning, fiscal year financial margins for supplies, and number and cost of expired supplies.

**Evidence-Based Support**

A review of the literature was multifaceted and focused on the current state of the healthcare supply chain in general, support for Lean based methods such as the two-bin system in the healthcare supply chain, and methods for evaluating and sustaining efficient supply chain outcomes over time. Quantitative and qualitative evidence reveal many challenges in healthcare supply management including a lack of data standardization, a variation in processes, and a lack of quality measures (Elmuti, Khoury, Omran, & Abou-Zaid, 2013). However, the literature also revealed facilitators of positive outcomes including information sharing, inter-organizational communication, and partnerships with suppliers (Elmuti et al., 2013). The literature reviewed indicated a need for additional supply chain research specific to healthcare; especially related to long-term strategies for successful initiatives (Kim & Kwon, 2015). Smith, Nachtmann, and Pohl (2011) have done significant work to develop an eight dimension taxonomy of 40 healthcare supply chain quality metrics based on literature review and expert interviews supporting the idea that use of universal supply chain quality metrics is vital to successful supply chain management.

A wealth of evidence exists describing Lean Six Sigma methods in healthcare quality improvement projects (Farrokhi, Gunther, Williams, & Blackmore, 2015; Poksinska, Swartling, & Drotz, 2013); however, there is a lack of evidence for such methods in specifically developing the two-bin supply system in settings similar to the cardiac catheterization/interventional
radiology lab setting. There is beginning support for the two-bin system, with multiple hospitals reporting improvements after implementing the system (Donnelly, Forester, & Donnelly, 2016; Aguilar-Escobar, Bourque, & Godino-Gallego, 2015) Another surgical department reduced their supply usage by 70-80% and significantly decreased set-up times using Lean interventions (Farrokhi et al., 2015); however, although their changes were Lean based, they were not two-bin system specific.

Conclusion

Assessment of the microsystem and current literature lay the groundwork for development of the two-bin supply system project to improve supply chain outcomes. Already established support from microsystem leadership and staff as well as recent well-accepted supply chain changes are the major facilitators for this project. Barriers include space constraints of the current storage cabinets, sterility requirements in the procedure rooms, and simultaneous changes that may make determining effects of this specific intervention difficult.

The remainder of this evidence-based protocol will further investigate the literature in support of the project, describe the Lean Six Sigma conceptual framework used to outline the project's implementation, and detail the protocol and evaluation once it has been applied within the microsystem. In conclusion, this scholarly project will be focused on implementing a two-bin system in a cardiac catheterization and interventional radiology department by using Lean Six Sigma methodology to frame the planning, implementation, and evaluation stages. The goals to decrease waste and variation in the supply process are ultimately focused on improving patient care and safety, aligning with the microsystem's prioritization of quality cardiac and vascular care.
Chapter 2: Literature Review

The combined cardiac catheterization and interventional radiology department of a Midwestern 340-bed hospital performs a variety of procedures that include cardiac diagnostic and interventional catheterizations, numerous radiological interventions, and neurological procedures. Due to the wide range of treatments and around the clock on call availability for emergent procedures, over 2700 different supply types are kept in the department and must be maintained at all times to ensure availability for patient care. While these supplies include standard patient care items, the department also stocks a variety of specialized catheters, medications, and other equipment specific to their practice. Hence, the supply chain process for ordering, tracking, and maintaining inventory of this many items is very complex. Over the past 1-2 years, leadership and staff noted recurrent issues with supplies missing when needed for a procedure as well as frequent overnight shipments, expired supplies, and generalized staff dissatisfaction with supply processes; all of which should be minimal to nonexistent in a busy procedural department. Since September 2016, the microsystem has been undergoing a long term, three phase, Lean based reconstruction of their supply processes with goals to achieve patient safety, quality care, and effective management of department costs by having the required supplies available and properly stocked to ensure availability for patient care.

In this chapter, a literature review will be presented that addresses the following clinical question: In a complex cardiac catheterization and interventional procedures setting, does transitioning to a Lean based two-bin (kanban) supply storage and restocking process contribute to improved supply chain outcomes when compared to a person dependent one-for-one supply chain system? While the goal of this literature review is to assess evidence for application of the two-bin system, it will also analyze literature regarding the current status of the healthcare
supply chain and research on the use and sustainability of Lean based interventions in healthcare. In this literature review, the methods for literature search will be discussed followed by review and discussion of the articles and overall findings including strengths and gaps in the literature.

Methods

Initial searches of the literature were conducted through the Grand Valley State University library databases and via specific databases including PubMed and CINAHL. A variety of search terms were used to find relevant articles including "healthcare supply chain," "importance of supply chain management in healthcare," "Lean healthcare," "kanban in healthcare" and "two bin supply system in healthcare." Findings were limited to articles published in the last 5 years in English. Over 30,000 articles total were returned during these searches. Due to the large number of articles, they were analyzed for relevance to the clinical question prior to inclusion in this review. Articles were limited to those including outcomes of two-bin (kanban) implementation, those in a healthcare setting similar to the one in question, articles providing relevant information about the current state of the healthcare supply chain, or sustaining supply chain interventions. Thus, the search yielded seven articles applicable to the clinical question. In addition to the library review, multiple searches of the Agency for Healthcare Research and Quality and other healthcare organization websites for guidelines and protocols specific to healthcare supply chain processes failed to return any results specific to the clinical question, revealing a substantial gap in the literature.

The selected articles are presented in table form in Appendix A including methods, sample population, and analysis of results for each. The articles have been split according to three themes: two examining the current state of the healthcare supply chain, three supporting the application of Lean and kanban processes, and two regarding strategies to maintain sustainability.
of supply chain interventions. Articles will be reviewed in terms of methods, level of evidence, major strengths and weaknesses, and their application to the clinical question.

**Current Status of the Healthcare Supply Chain**

Articles defining the current status of the healthcare supply chain seek to identify challenges and facilitators to effective supply chain management. Elmuti, Khoury, Omran, and Abou-Zaid (2013) analyzed the U.S. healthcare industry supply chain using a combination of quantitative and qualitative methods. After nine research questions and a research framework were identified, a Likert scale survey was sent to over 700 healthcare organizations. Survey questions addressed an independent variable, supply chain management initiatives and activities, and a dependent variable which was effectiveness including productivity, performance, quality, and dependability of the supply chain. The qualitative portion included interviews of 30 healthcare professionals skilled in supply chain management from 20 medical centers. Participants were asked for feedback on supply chain facilitators, barriers, and for their thoughts on how effective supply chain management affected performance and outcomes in their own facility.

By using a regression analysis, the authors found that the majority of variance in productivity, quality, and cost was directly related to supply chain initiatives, which is congruent with previous research on the topic (Elmuti et al., 2013). Facilitators of successful supply chain include strategic information sharing, collaboration within the organization, and partnerships with suppliers and healthcare providers (Elmuti et al., 2013). The authors conclude that healthcare supply chain management is beneficial to organizations, evidenced by both the quantitative analysis and in-depth qualitative interviews.

A literature synthesis by Kim and Kwon (2015) studied the status of the healthcare
supply chain and revealed similar findings. Their review of 43 articles was divided among four themes: overviews of healthcare supply chain, comparative studies on commercial and healthcare supply chain management, major tools for healthcare supply chain, and the barriers of adopting healthcare supply chain management. Findings of the review support the organizational benefits of strategic supply chain management, but also highlight the need for long-term strategies to sustain successful initiatives even when financial constraints may pressure leaders to look for quick solutions.

Indeed, challenges to management of supply chain identified by Elmuti et al. (2013) align with Kim and Kwon's (2015) findings and include conflicting goals, lack of data standardization, and lack of quality performance measures, each of which could potentially impair sustainability of interventions. Application of these results to clinical use includes organizational focus on cooperation and communication between all aspects of the supply chain and long term commitment to supply chain excellence to ensure maximal benefits of a well-managed process.

**Application of Lean Interventions**

In the microsystem that is the focus of the clinical problem in question, interventions to improve the current supply chain will be based on a Lean Six Sigma framework. Adopted from the auto manufacturing industry, Lean Six Sigma is becoming increasingly widespread in healthcare (Farrokhi et al., 2015). Although there were no studies found that were specific to the combination cardiac catheterization and interventional radiology setting, successful studies have been conducted regarding the use of Lean interventions in similar healthcare settings.

The intervention planned for the microsystem is the implementation of a kanban two-bin supply stocking and delivery system. Stemming from Lean methodology, the goal of the kanban system is to only deliver a set amount of each supply on an as needed basis based on a visual
sign such as a card or empty box (Aquilar-Escobar et al., 2015). The goal is to reduce dependence on the end user, decreasing time spent managing supply and increasing efficiency (Donnelly et al., 2016). Typically, supplies are stored in two adjacent bins. When the first is emptied, the empty bin is placed in a designated visible area signifying that the item needs to be restocked. Then, the filled bins are placed in the back so that items that were stocked earlier are used first (Donnelly et al., 2016).

Donnelly, Forester and Donnelly (2016) also acknowledge a gap in the literature about radiology supply chain specifically and explore the use of the kanban two-bin supply system in both the imaging and interventional "nodes" of the radiology department of a new children's hospital two years after its implementation. Approximately 700 supply types were maintained using this system, which reported a 98.08% fill rate (100% - stock out rate) in imaging and 98.7% in interventional radiology. The hospital also reported time saved searching for supplies, a decrease in expired supplies, and improved visibility of supply problems. Aquilar-Escobar, Bourque and Godino-Gallego (2015) conducted the only known study of hospital staff satisfaction with the kanban system by administering a Likert scale survey to 208 nursing staff members of a large hospital group in Spain. Analysis of the results showed satisfaction levels significantly higher than those associated with the previous supply system. The authors report major advantages of the kanban system to be decreased nurse time spend managing supplies, less storage space required, improved organization, and fewer expired items (Aguilar-Escobar et al., 2015). Clinically, this equates to improved nurse satisfaction, improved patient care, and positive organizational outcomes (Aguilar-Escobar et al., 2015).

Also based on an implementation of Lean methods, Farrokhi, Gunther, Williams and Blackmore (2015) conducted a study with the purpose of evaluating a quality improvement
project at Virginia Mason Medical Center. The project's ultimate goal was to improve quality and efficiency of the operating room surgical instrument availability. The intervention group included 885 minimally invasive spine surgeries and 156 deep brain stimulation procedures monitored over three and half years both before and after a Lean 5S (sort, simplify, sweep, standardize, self-discipline) improvement event, while the control group of 354 open spine surgeries and 134 craniotomies was tracked over the same time period without any Lean intervention to their surgical trays. Findings included a 70-80% reduction in the number of surgical instruments needed on standardized surgical trays, a 4.9 minute reduction in set-up time, and an estimated extrapolated cost savings of $2.8 million/year if the hospital were to fully implement the Lean intervention. The authors’ conclude that Lean quality improvement leaders can employ simple ways to drastically reduce waste while retaining value in the supply process (Farrokhi et al., 2015). Although this study reports good evidence for the use of Lean, it may difficult to apply these results to another setting or type of supply chain as this study was limited to one setting.

Sustainability of Interventions

A common conclusion of the literature already discussed is the need for sustainability of interventions to ensure long term benefits of effective supply chain management are maintained. Indeed, multiple sources comment on the cultural shift microsystems must undergo in order to sustain Lean processes (Farrokhi et al., 2015; Poksinska, Swartling, & Drotz, 2013). Smith, Nachtmann, and Pohl (2011) specifically recommend utilizing supply chain metrics to monitor outcomes over time. Their development of an eight-dimension taxonomy of 40 supply chain quality metrics, based on literature review and expert interviews, supports the idea that "development of quality metrics that can be used universally across the healthcare supply chain"
is vital to successful supply chain management. The authors reviewed 10 key papers, interviewed 14 healthcare supply chain professionals, and also utilized their 2009 survey of 100 healthcare supply professionals to develop an extensive list of metrics. Eighty-five percent of these metrics were classified under only three of the eight quality dimensions including performance, conformance, and features (those affecting efficiency and effectiveness). Their recommendations can be used to inform supply chain interventions in the microsystem being studied, and support the use of quality outcome metrics during supply chain changes and over time to maintain consistency and reliability.

In addition to consistently using quality outcome metrics to sustain supply chain management, Poksinska, Swartling, and Drotz (2013) identify another aspect of sustainability: leadership strategies throughout Lean improvement programs. In their literature review, Kim and Kwon (2015) conclude that "supply chain deployment is a long-term strategic decision and it is a complex and dynamic process" (p. 51). According to Poksinska et al. (2013), many Lean interventions do not demonstrate sustainability over time. This requires a change in culture, which in turn requires a change in leadership approaches. By conducting five in-depth case studies including interviews, shadowing managers, and review of key organization documents, Poksinska et al. (2013) sought to determine characteristics of Lean leadership, methods used in Lean management, and relationships to contemporary leadership frameworks. Three major conclusions were made from the study, each of which is applicable for use in other healthcare settings such as the cardiac catheterization and interventional radiology department. First, Lean leadership shares characteristics with transformational leadership, motivating employees by empowering them and focusing on personal improvement. Second, much responsibility was transferred to employees and Lean managers focused on facilitating employee growth and
empowerment with a coach-like role. This process was related to the servant-leadership style. Finally, a connection was made to self-managed teams. The case studies presented demonstrated that as organizations matured in their use of Lean, teams became increasingly self-managed and the managers' roles were that of providing direction as needed. Poksinska et al. (2013) conclude that these Lean leadership strategies are necessary to implementation and sustainment of Lean quality improvement efforts. Leaders have the ability to steer changes in the unit, driving the cultural shifts required to keep improving processes (Farrokhi et al., 2015).

Conclusion

While the literature reviewed provides sufficient evidence to guide interventions addressed in the clinical question regarding improvements to the microsystem supply chain, the process revealed significant gaps that are opportunities for future research. Many studies described supply chain in manufacturing; but there is a lack of research describing the supply chain in the healthcare sector. This is unfortunate as healthcare is lagging in utilization of effective supply chain management (Elmuti et al., 2013). Similarly, although healthcare organizations have many unique characteristics, some studies compare commercial supply processes to those in healthcare, indicating a need for more studies in healthcare specifically (Kim & Kwon, 2015). Elmuti et al. (2013) also identifies a lack in "empirical research that clearly links healthcare supply chain initiatives to overall organizational effectiveness" (p. 131) which is concerning for those implementing supply management practices. Experts also identified a need to bridge the gap between supply chain quality and patient safety by developing metrics that could be used on a daily basis based on the current lack of assessment of reliability, durability, and quality metrics in healthcare supply chains (Smith, Nachtmann, & Pohl, 2011). More relevant to the setting in question, searches of the literature for articles pertinent to
interventional radiology or cardiac catheterization supply were unsuccessful. Donnelly et al. (2016) states their efforts to find literature regarding supply chain in the radiology setting did not produce any results; therefore, evidence for interventions must be extrapolated from research in other settings which can prove to be problematic.

The articles selected for this review support the need for and significance of supply chain interventions, the effectiveness of Lean based methods for such interventions, and the use of specific strategies to sustain changes including utilization of quality metrics and evolving leadership styles. Much of the literature reviewed consists of descriptive evidence, surveys, and case studies where, although quantitative data is presented, the studies cannot be considered controlled trials. There is also a significant amount of literature focused on synthesizing prior literature on the subject. However, due to the lack of strong evidence such as meta-analysis, clinical practice guidelines, and controlled trials, the strength of the literature concerning the clinical question should be considered weak to moderate. Although the setting and proposed intervention are fairly unique, there is a need for stronger quantitative evidence in support of Lean methods and specifically the two-bin supply system. That being said, the current evidence reviewed will be used throughout the cardiac catheterization and interventional radiology supply chain process changes by informing the interventions to be put in place and their sustainability over time.
Chapter 3: Theoretical Framework

The supply chain management of a cardiac catheterization and interventional radiology department in an urban Midwestern hospital has been undergoing changes to reconstruct their supply process, transforming their previously Pyxis-based, person dependent system into one that is process dependent with minimal variation. For this evidence-based project, a two-bin supply storage and ordering system will be implemented in the department’s four procedure rooms. With the goals of decreasing patient risk related to missing supplies and minimizing supply chain costs to the department, a conceptual framework is necessary to guide this intervention. Lean Six Sigma is a combination of two well-known quality improvement methods focused on minimizing process variation and waste while at the same time standardizing work flow (Kubiak & Benbow, 2009). This paper will define the components of the Lean Six Sigma framework with a focus on the DMAIC (define, measure, analyze, improve and control) model and will then explore its application of the DMAIC model to the supply chain improvement process. A visual representation of how the model will be utilized is also presented in Appendix B.

Definition of the Framework

Lean Six Sigma refers to what has become a blended framework of the Lean and Six Sigma quality improvement methods, both of which originated in the manufacturing industry. Lean, developed in the Toyota production industry, focuses on waste reduction (Kubiak & Benbow, 2009) and an overall cultural change (Vest & Gamm, 2009). The five principles of Lean according to the Lean Enterprise Institute are defining value, identifying steps in the value stream, eliminating steps that do not create value, improving flow toward the customer, and allowing customers to receive value from the process. (Moraros, Lemstra, & Nwankwo, 2016).
Steps are repeated as necessary. Six Sigma is focused on reducing variation within a process (Kubiak & Benbow, 2009) by using statistical analysis to identify root causes and establish quality metrics (Smith, 2003).

Because process improvement frequently uses aspects of both Lean and Six Sigma, the two are often utilized together to achieve the best outcomes. Where Lean provides a fast, action-based approach that can quickly address the "low-hanging fruit" to come up with solutions, Six Sigma then uses statistical analysis to dig deeper into the problem (Smith, 2003). Combined, Lean Six Sigma is "a fact-based, data-driven philosophy of improvement that values defect prevention over defect detection. It drives customer satisfaction and bottom-line results by reducing variation, waste, and cycle time, while promoting the use of work standardization and flow. . . It applies anywhere variation and waste exist" (Kubiak and Benbow, 2009, p. 6-7).

**DMAIC Model**

Derived from the Lean Six Sigma methods, the DMAIC model will be the focus of the remainder of this chapter. DMAIC is a framework for quality improvement based on data collection and analysis that can be used either on its own or along with other aspects of Lean Six Sigma (Borror, 2009). DMAIC is an acronym for a model that contains five main phases describing the process of quality improvement: define, measure, analyze, improve, and control (Borror, 2009). Taner, Sezen and Jiju (2007) identify each of these steps: 1) define the problem including opportunities for improvement, scope, and goals of the interventions; 2) measure current status by comparing outcomes to required standards; 3) analyze root causes, best practices, and identify hypotheses; 4) improve by implementing interventions, testing and standardizing solutions; and 5) control long-term outcomes by initiating monitoring strategies to
ensure sustainability. The premise of DMAIC is that the phases build on each other. Each phase informs the next, constructing a foundation for long-term sustainability (Berardinelli, 2012).

Literature supports the successful use of Lean Six Sigma approaches such as DMAIC for quality improvement in a variety of healthcare settings. A review of 9 studies using Six Sigma to make improvements in areas including hand hygiene, surgical antibiotic prophylaxis, radiology scheduling, central line associated bloodstream infections, and hospital acquired urinary tract infections, among others, reported positive outcomes across the board (Vest & Gamm, 2009). More specifically, the DMAIC model is an optimal quality improvement method for solving complex, high risk problems because it prevents a team from skipping steps in the process, which could prove detrimental (Berardinelli, 2012).

Due to the complexity, variation, and potential for patient risk in the cardiac catheterization/interventional radiology supply chain process, DMAIC can be an effective framework for improvement. The microsystem has already undergone one of three kaizen phases as part of an ongoing supply chain improvement process, which is a method in line with the Lean Six Sigma and the DMAIC model (Berardinelli, 2012). Interventions within the process continue to build on each other, paving the way for continued decrease in waste and variation within the system. Phase one consisted of turning off the powered Pyxis storage cabinets and color coding all supplies according to their ordering process. The proposed two-bin kanban storage system implementation will make up phase two and three of the kaizen interventions through the purchasing of cabinets (phase two) and installation of kanban (phase three). The following paragraphs will describe how DMAIC will guide this intervention. Appendix B presents a visual representation of the DMAIC model and its application to this project.
Define. The cardiac catheterization and interventional radiology supply chain has been an ongoing problem due to the complexity of the system. The "define" step of DMAIC requires identifying the issue at stake; it is essentially the clinical problem. In the microsystem's supply chain process, multiple problems have been a source of frustration. Staff were frequently reporting items missing in the morning even though they should have been stocked, and were at times missing devices vital to specific procedures. Items frequently had to be shipped overnight to ensure availability, which costs considerably more than standard shipping. At times, the department has even needed to urgently obtain devices from neighboring facilities when they should have them in stock. This has caused delays in care and potential patient safety risks. The CNL has also spent a significant amount of time (2-3 hours per day) managing discrepancies when her time could be spent focused on other responsibilities.

Also included in the first step of DMAIC is defining goals. The goal of the proposed two-bin system intervention is to reduce unit costs, improve patient safety, and ensure patient satisfaction. We will know changes are effective by measuring outcomes and assessing staff satisfaction with the interventions, which will be further discussed later.

Measure. Obtaining baseline measurements of microsystem supply chain outcomes will allow comparison to outcomes after implementation of the proposed change. As previously discussed, Smith et al. (2011) identify approximately 40 ways to measure supply chain status within eight dimensions: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. Currently being monitored by the department's CNL and the MSN student are the frequency and cost of overnight shipments, incidence of delayed procedures related to supply needs, and the number of supplies missing or critically low each morning prior to the start of procedures. As the microsystem has already completed the first
of three kaizen improvement phases, these metrics will be continually obtained to monitor the status of the supply chain. Gauging staff engagement and support of the project may also be key indicators to determine buy-in and potential for sustainability.

**Analyze.** The analysis phase requires identifying the root causes of poor outcomes related to the clinical problem. In the supply chain process, leadership and staff realized that workarounds have been in place such as borrowing supplies in emergencies, use of an overstock cart, and a generally person-dependent system. Multiple ordering processes, inaccurate PAR levels, and minimal staff knowledge about the supply chain have all contributed to waste and variation. The lack of a process-dependent system led to missing supplies, frequent overnight shipments, increased time spent focused on supplies, and risk to patient safety related to delays in care. As an example, close analysis of orders placed for a certain catheter revealed the item to be on backorder. Approximately 30 orders had been placed and not filled, with no method of communicating this to staff. The CNL spent a considerable amount of time investigating the root cause of this problem, one of many related to variation in the ordering system. Similarly, most instances of supply issues in the department have been related to variation in ordering and incorrect counts registered in the inventory system.

Analysis also includes formation of a hypothesis, which is based on goals of the process improvement. A hypothesis for the two-bin supply storage intervention would be that the proposed change would decrease the number of overnight shipments and supplies missing from rooms in the morning. Based on this analysis, the model then allows the quality improvement leader to modify and redesign the intervention as needed before moving on to the improve phase.

**Improve.** The improve phase finally involves putting changes into practice to eliminate the root causes of the problem (Berardinelli, 2012). Up to this point, improvements made to the
microsystem's supply chain have included turning off the Pyxis system and transferring delivery of supplies kept in central supply dispatch to a nightly scanning and re-stocking process completed by central dispatch. All supplies have also been color coded with a labeling system to clearly identify their source (ex: central supply or special order). The proposed next process change is the implementation of the two-bin supply system, which will likely occur in April or May 2017. Actual implementation will be carried out by the CNL and MSN student, but will also require significant input and assistance from frontline staff and central supply staff. The goal of the two-bin system is to standardize supply par levels and facilitate visibility of low stock, both of which should decrease variation and waste in the process.

Testing and standardizing changes is a key part of this phase of DMAIC, which for the department means ensuring that changes facilitate the goal to transition to a process-dependent supply chain instead of one that is person-dependent, causing potential for gaps in the system.

Control. Finally, the control phase of DMAIC is essential to sustain changes. This phase requires putting long-term mechanisms into place to make sure improvements are consistently utilized after implementation. Evidence suggests that healthcare organizations do a poor job of supply chain assessment and that sustaining metrics to assess performance over time is key to improving quality (Smith et al., 2011). The goals and measurements of the microsystem that were previously described can be used as controls to monitor progress. For example, continuing to track overnight shipments, supplies missing in the morning, and delayed procedures would all be effective ways to verify improvements. Staff engagement and satisfaction with new processes will also help predict sustainability. Financial outcomes should also be measured to determine success of the interventions and demonstrate return value on the project. The overall goals of this phase are to define reliable, long-term plans to maintain optimal outcomes (Berardinelli, 2012).
Conclusion

In conclusion, the DMAIC model will be a useful framework to guide the two-bin storage system proposed in the complex cardiac catheterization and interventional radiology supply chain process. Because DMAIC requires all steps in the improvement process to be completed, it ensures integrity and sustainability of changes. The framework allows for modification of improvements as needed to support positive outcomes. As will be discussed in depth in the next chapter, the steps to implementation of the two-bin system will follow the DMAIC framework throughout all phases of planning, implementation, and evaluation of the project.
Chapter 4: Clinical Protocol

The goal of implementing a two-bin kanban supply storage system in the procedure rooms of a cardiac catheterization and interventional radiology lab is to minimize patient safety risk and supply chain costs. While initial planning and precursory changes for the kanban two-bin system have been in progress since September 2016, the official transition will occur in the summer and fall of 2017. This chapter consists of a step-by-step description of the proposed supply chain intervention based on the DMAIC method, a brief cost benefit analysis of the project, and discussion of potential challenges to implementation and how these challenges will be addressed.

Pre-Implementation Protocol Steps

In following the steps of the DMAIC model, the define, measure, and analyze steps have been completed in preparation for putting the two-bin system into place. These will briefly be discussed here as they are vital steps in the protocol, and will be followed by a more detailed description of plans for the improve and control steps of the model. For a visual reference of the DMAIC model as it pertains to the protocol, see Appendix B.

1. Define: The problem was defined during the summer and fall of 2016 and has been discussed at length in previous chapters of the protocol. To summarize, variation and waste in the supply chain ordering and storage system was posing a risk to patient safety, causing delays in care, and required excessive time by staff and leadership to manage supplies in the department. At this time, a group of key stakeholders was gathered to form a project committee including the CNL, manager, and leadership from central supply dispatch. This group of stakeholders determined that a solution was necessary to achieve patient safety and quality care by having all supplies available for procedures at the scheduled time.
2. Measure: After identifying frequent frustrations with the supply system, the CNL began measuring department supply chain outcomes in September of 2016. This step served multiple purposes to acquire baseline data for the proposed two-bin system, monitor initial phase one process changes, and further drill into root causes of the problem. Outcome measures included number and total cost of overnight shipments, frequency and cost of expired supplies, and number of supplies missing in the morning after nightly stocking was completed. The measurement step also included evaluation of staff and physician satisfaction with the supply process via regular conversations and feedback. Data collection has been sustained since September 2016 and will continue through and beyond implementation of the two-bin system.

3. Analyze: Throughout and following the define and measure steps, the CNL, MSN student, and central supply dispatch leadership were able to analyze causes of poor supply system outcomes. It was determined during September and October of 2016 that the system in place was highly person-dependent on a departmental supply technician and that this contributed to excessive variation and waste. After analysis of potential best practices and Lean based solutions, the team agreed to move forward with three kaizen phases of supply process changes, the final of which will be full implementation of the two-bin kanban system.

The Improvement Phase

For practical purposes, this protocol will not go into full detail about the process changes that have been already been put into practice. To briefly summarize, these changes included turning off the existing Pyxis storage cabinet system in September 2016 (kaizen phase I) and labeling all supplies one of four colors identifying their source. Central supply now manually scans par levels and restocks hospital stock items each night, which will remain in place with the two-bin system. Additionally, the 0.9 FTE departmental based supply technician was eliminated.
and 0.25 of these FTEs were allotted to a central supply dispatch tech to keep up with daily non-stock and special orders. The team of stakeholders that was developed in 2016 has maintained close communication and continues to meet as needed.

The next steps and transition to the two-bin system will occur during the spring and summer of 2017. First, in March and April the CNL will finish obtaining quotes and move forward with plans to purchase new cabinets in the procedure rooms. This will be discussed further in detail later, but requires determining the official source of funding for the project. By the end of April, the goal is to purchase and organize 3 new catheter carts. By August, additional carts to house remote stock items such as vascular and neuro wires will be purchased and organized. These carts must be purchased prior to the carts that will be used for the two-bin system because they will help prevent damage to items as well as meet The Joint Commission requirements for completely enclosed storage, which is currently an issue. These carts are also cheaper and therefore easier and faster to obtain.

The goal is to secure capital for the main two-bin cabinets by this summer so that the CNL and MSN student can move forward with purchasing the cabinets by August. When the cabinets are purchased, installation will likely take place over a weekend to avoid interfering with scheduled cases. Installation will include not only physically putting the cabinets in place, but emptying the current cabinets and reorganizing all supplies into two bins each to transition to the new system. Bins will have to be labeled and organized for functionality according to staff needs and preferences. This will require significant involvement of both the CNL and frontline staff.

The ordering and restocking system of the two-bin cabinet supplies will remain the same, where a supply tech scans the items that need restocked each night and then delivers them from
central supply. Any logistical issues with this system will be addressed during the first couple of months after implementation. Additionally, some teaching will be required with staff to make sure they know how the two-bin system works and what their responsibilities are. Although staff are already fully aware of the changes that are coming, the CNL and MSN student will make sure any necessary education occurs during and immediately following the official transition. See Appendix C for a Gantt chart of the protocol timeline.

**The Control Phase**

Berardinelli (2012) emphasizes the importance of the control phase of the DMAIC model because it allows for quick identification of problems and fine tuning interventions if needed. Following implementation of the protocol, it will be crucial to monitor long-term outcomes to ensure the change is both successful and sustainable. Conveniently, many measures will already be in place. Steps to the control phase will include the following:

- Continue long term data collection of supply chain outcome metrics including number and cost of overnight shipments required per month, number and cost of expired supplies per month, and number of supplies missing in the morning after nightly stocking per month.

- Compare quarterly and fiscal year total inventory financial margins to obtain an idea of the overall status of supply chain costs and savings for the microsystem. This will also need to be monitored long term as initial costs and time to implement the protocol may skew results until the two-bin system is fully integrated and functional.

- Monitor staff engagement and satisfaction with the two-bin kanban system on a regular basis through daily conversations, feedback, and staff meetings. The CNL should strive
to maintain open communication with staff as this will encourage both positive and negative staff feedback, optimizing outcomes of the protocol.

- Meet with the original team of stakeholders regularly to review outcomes data and modify the protocol design as needed.
- Regularly organize and display data for department staff. This should include data regarding financial savings, patient safety, and number of missing and expired supplies so that staff can see how the changes are impacting their work and quality of patient care.

**Cost Benefit Analysis**

A cost benefit analysis is used to estimate all potential costs and value from a proposed project (The Economic Times, 2017) and can also help identify resources required. By identifying the necessary resources, personnel, and technology needed to fully implement the two-bin kanban system, we are able to analyze the potential short and long term costs and benefits of the protocol. This information can be used to drive any necessary changes to the microsystem business plan or to the project design.

**Costs.** Costs to consider prior to carrying out the protocol include the necessary resources and capital funding for the project. Most pressing is the need for new storage cabinets in all four procedure rooms prior to transition to the two-bin system. Quotes completed by a healthcare storage systems representative in mid-March estimated costs to be approximately $14,000 for new catheter storage carts and $25,000 for all new supply storage cabinetry. This did not include predicted costs for actual storage bins. The money needed to fund this project will either be operationalized to the microsystem budget over time (no more than $2500 per month) or will be obtained via the organization's capital budget process. This process would require approval from senior leadership and the capital committee, which could take an unknown amount of time.
Either way, at this point, funding is the biggest barrier to the time frame of the project. Until funding and the new cabinets are obtained, current processes will remain in place which is not ideal.

The two-bin system will also require a significant amount of unit leadership and staff time to physically install. Procedure rooms will have to be shut down to install the new cabinets and reorganize all supplies into the two-bin system. Depending on the procedure schedule, this may impact the ability to schedule the normal amount of procedures or may require additional staffing hours to complete the same amount of procedures in fewer available rooms. Installation of new catheter and remote stock carts is estimated to take half a day per procedure room. Installation of the two-bin cabinets, however will require much more time and will likely take place during off hours over a weekend. Front line staff, the CNL, and MSN student will be the personnel responsible for organizing supplies into the two-bin system as they are the ones with a working knowledge of where supplies need to be stored. This will require compensation for any additional staff hours and potentially detract from productivity levels.

**Benefits.** There are many potential benefits of transitioning to the two-bin system, some of which are already impacting the unit. The overall goal of the protocol is to have supplies available for procedures when and where they are needed. By achieving this goal, patient safety and procedure delays related to missing supplies should be positively impacted as well. The CNL is able to track these outcomes and quantify time and costs involved, hopefully improvements in trends.

Notably, one of the initial steps in preparation for this project was turning off the current Pyxis cabinets' integrated ordering system in September 2016. This technology costs approximately $100,000 per year in service fees so is already saving significant funds. Using the
two-bin system will not require any additional technology, as the current system of using a handheld scanner to scan in the items that need restocking each night will remain in place.

Although initially there were concerns about whether utilizing a two-bin system would require additional storage space, conversations with an experienced healthcare storage solutions representative suggest the opposite. The two-bin system allows for a lower average par level of supplies which reduces space required and the number of supplies left on the shelf past expiration (Aguilar-Escobar et al., 2015). Although the monetary savings related to reducing expired supplies via the two-bin system cannot be predicted or quantified at this point, this is something that has been and will continue to be monitored to compare and determine the monetary benefits over time. Literature review supports this and other potential benefits of the two-bin system including better overall organization and a faster ordering process (Aguilar-Escobar et al., 2015). Other financial benefits include the potential for further reduction in overnight shipments. A report of overnight shipments to the department can be obtained from central supply to quantify these savings each quarter.

One of the major benefits of implementing the two-bin system will likely be staff and physician satisfaction with the process. Initial changes to the supply process have already proven this to be true as evidenced by ongoing conversations and input from nurses, techs, and physicians. The CNL has very close daily involvement with front line staff and physicians and can easily monitor this. Nurses and technicians have played a part in some of the supply chain changes up to this point, including daily monitoring of which items are missing from their procedure rooms. Staff members have commented on the drastic decrease in missing items up to this point and are ready for continued improvements.
Potential Challenges

A couple prominent challenges will likely impact the implementation process of the protocol. As discussed, procuring funding for the new cabinets is the most likely factor to impact the project's time frame. Because the two-bin system cannot be implemented until new cabinets have been purchased and installed, this step is crucial. As of March 2017, final decisions still need to be made regarding the source of funds. Logistically, there are challenges to implement the system that cannot be avoided as well. Although purchasing new cabinets for the two-bin system is the goal, new catheter carts and remote stock supply carts must be purchased first. This was included in the implementation steps, and must occur since The Joint Commission mandates to have supply carts with full front doors in place. The goal, however, is to complete these steps as soon as possible while continuing to prepare for the two-bin system.

Additionally, because the procedure rooms are a sterile area, this may pose a challenge to the two-bin system. In the ideal two-bin system, empty bins are taken to central supply to be refilled and then returned, which may not be possible in this setting. To address this challenge, the MSN student and CNL will need to determine regulatory guidelines for procedure areas and identify solutions to this problem if needed. There may be possible solutions such as using a labeled card to assist with the restocking process.

Conclusion

To conclude, implementing the two-bin kanban system in the cardiac catheterization/interventional radiology setting will follow the steps outlined by the DMAIC model of the Lean Six Sigma method. The intervention, which is already in the planning and precursory stages, is scheduled to be completed in August of 2017 pending obtaining funding and purchasing new cabinets in the procedure rooms. Key to sustaining success of the protocol will be continual
monitoring of the new process and tracking supply chain outcomes, staff satisfaction, and patient safety indicators.
Chapter 5: Protocol Evaluation

In the cardiac catheterization lab and interventional radiology setting, a protocol for improving the supply chain system via installation of the kanban two-bin system was outlined and initiated with the goal of improving supply chain outcomes. This chapter will describe the actual process of implementation and outcomes observed thus far. Sustainability strategies will be discussed along with an exploration of the overall strengths, weaknesses and limitations of the project. Because this project was executed as an MSN scholarly project, this evaluation chapter will also include a brief reflection of how the MSN Essentials were utilized throughout.

Evaluation of Protocol

Although many changes have been made to the department’s supply chain process since September 2016 as part of a planned three phase Kaizen improvement project, implementation of the kanban two bin system has proven to be challenging. To briefly summarize, the initial supply process changes included turning off the Pyxis system so that supply staff would scan par levels and stock supplies at night, and then transitioning the full time department based supply tech to a 0.25 FTE central supply based tech. Plans for this protocol (the next kaizen phases) included transitioning to the two-bin kanban system prior to purchasing new cabinets because of predicted time and cost factors. However, it was determined that it would make more sense to reverse this order to reduce the amount of necessary reorganization and to meet The Joint Commission requirements as soon as possible. The planned timeframe for the kanban system was to obtain funding by April or May 2017 and purchase and install the new cabinets and kanban process by August 2017. As of June 2017, steps have been taken toward these goals; however, the overall timeframe was not met primarily due waiting for capital funding approval. In March, the CNL and MSN student worked with a storage solutions representative to obtain measurements and a quote for the cabinets needed in the procedure rooms. This information was submitted to the
capital budget committee for review, which is not yet complete. Because of this, the timeline for the project was pushed back until the funding source is officially determined. If approved for capital funding, installation of new cabinets and the kanban system should occur before the end of the year.

While the kanban system has not yet been implemented, the CNL and MSN student have regularly assessed the current processes and troubleshooted any supply incidents to continue to reduce variation and waste in preparation for kanban. For example, occasionally supplies are noted to be labelled as a special order when they are now stocked within the hospital. The CNL is able to fix this within the ordering system. Similarly, the MSN student has worked on creating sustainable processes to measure supply chain outcomes including identifying and quantifying expired supplies and the number of supplies missing in the morning after nightly stocking. Appendix E shows the table that was developed and provided for staff each morning to track the critically low or missing supplies in procedure rooms. The MSN student and CNL used this information over the past year to closely monitor daily supply needs and track trends over time. Small projects like this contribute to a healthier supply system overall and are paving the way for reduced variation in the system leading up to kanban installation.

Strengths of the Protocol

Many aspects of this project can be considered strengths and also contribute to sustainability of the protocol’s implementation. A major facilitator of the plan for kanban is that staff in the department have already worked through initial changes to the supply system and satisfaction and engagement with these processes so far is high. The department staff are generally very experienced, have a desire to learn, and are open to change. They also have a high level of respect for department leadership and are consistent about providing both negative and
positive feedback regarding processes and changes. Staff participate in daily assessments of the supply system including data collection, which gives them a sense of accountability and fosters engagement.

Also key to the sustainability of this project is the transition from a person based to process based system that kanban will build on. The goal of the kanban two-bin storage system is to turn identification of needed supplies and expiring supplies into a simple visual process that can be managed by any staff member or tech instead of one that was driven solely by one person. Having central supply absorb 0.25 FTEs provides accountability on their end, adding to the teamwork and support needed to sustain the project.

A major component of the protocol is data collection to compare supply chain outcome metrics before, during and after kanban has been initiated. Processes for collecting this data were put into place and continue to be refined. For example, central supply management provides data on the number and cost of overnight shipments each quarter. The CNL and MSN student have developed processes for staff to daily track supplies missing in the procedure rooms with a chart provided each morning (see Appendix E), and have continued to solidify a process for tracking expired items. Literature has shown that consistent measurement of supply chain outcomes is key to sustainability (Smith et al., 2011).

**Weaknesses of the Protocol**

There are areas of concern in the protocol that should be addressed. A significant weakness to the project is the unpredictable time frame related to the need for capital funding. This project depends on an outside source to be completed, which takes control of the project out of the hands of department leadership and staff. Although this is unavoidable, it poses a
significant threat to the project. Ideally, funding would come from within the department budget; however, that is not feasible at this time.

Another weakness is the lack of evidence-based practice that directly applies to the cardiac catheterization/interventional radiology lab setting. As discussed in Chapter 2, there are no studies of kanban implementation in this setting, which makes developing the protocol and sustainability strategies more difficult. Although the outcomes predicted after kanban implementation are promising, the lack of evidence is a concerning factor overall as there is no certainty that the intervention will be effective.

**Evaluation of Outcomes**

Outcome measures obtained to this point have shown that the initial supply process changes have already positively impacted outcomes. Due to variability and compounding factors that go into patient care in the department, obtaining data such as cases delayed by missing supplies is almost impossible to determine. However, other outcome metrics have been monitored. Appendix D includes line graphs for the outcomes of number of supplies missing in the morning and the number of overnight shipments required, both per month. This data will continue to be collected and will be used as baseline data to compare results following full implementation of kanban.

In September 2016, department staff began tracking the number of supplies that were missing or down to one left each morning before the start of scheduled procedures. The CNL and MSN student provided a form to be filled out for each of the four procedure rooms that included the type of supply, color of sticker (indicating it’s source), and the number left on the shelf (0 or 1). See Appendix E for this data collection tool. The graph shows results of this data collection from September 2016 through May 2017. The number of missing supplies decreased from 112 in
September to 20 in May. The noted decrease in number of missing supplies aligns with initial Phase 1 changes to the supply system including turning off the Pyxis cabinet technology and eliminating the department based supply tech position. Results have consistently been between 20 and 30 since January. Staff will continue collecting this data, which will be evaluated by the CNL on a monthly basis through the kanban intervention to determine its effectiveness in addition to supply process changes so far.

Data for the number of overnight orders was obtained retrospectively back to April 2016, 6 months prior to the first supply system interventions. This data is provided to the CNL by central supply management each quarter. The number of overnight orders is an indicator of the overall health of the supply chain, as overnight orders are required more frequently when supplies are not stocked effectively. An overnight order is required when a supply is either used so frequently that the stock is depleted or is identified as needed for a scheduled procedure in the next 24-48 hours. In April 2016, there were 14 overnight orders. This number has consistently trended down, with results ranging from 2-5 since October 2016. Calculations by supply chain management indicate that this reduction in overnight shipments leads to an annualized savings of over $5,700 (including freight and time spent per order). With the implementation of kanban, this outcome will also continue to be monitored by the CNL to assess the status of the supply chain.

Also important to note is the amount of capital saved by turning off the software based Pyxis cabinets in September 2016. Costs for this program and required maintenance is approximately $50,000 per year, equating to instant savings. Although the Pyxis process is now done manually, the completion of kanban will streamline the process into one that is more streamlined and efficient.
Implications for Practice

The results of the protocol so far indicate that a Lean Six Sigma based systematic approach to reconstruction of a complex supply chain is effective at improving outcomes. Department leadership is hopeful for continued positive outcomes following the full implementation of the kanban intervention. Regular and purposeful evaluation of the discussed outcomes to assess the state of the supply chain is necessary for sustainability and must be made a priority by leadership and staff.

This project has potential to be applied to other healthcare supply chain systems. Considering the lack of literature currently available regarding the kanban system and particularly its adoption in the cardiac catheterization and interventional radiology setting, results of this project address a need in the literature. Additionally, due to the complexity and large number of supplies in the department’s supply chain, the outcomes of this project can likely be easily applied to microsystems with smaller, less complex systems.

Project Limitations

The most significant limitation to the project is the method of data collection used to measure the number of missing supplies in the morning before the start of procedures. To collect this data, a half sheet of paper was posted for each procedure room in the morning for staff to fill out the supply missing or low and its source. When this started in September 2016, staff were diligent about completing this each morning; however, more recently the data collection has not been as frequent, suggesting that data may not be as complete as it should be. This decrease in sustainability may be due to a lack of diligence to the process by both staff and leadership. Reliable data is vital to evaluating outcomes with implementation of the kanban system, so this is something that needs to continue to be addressed. A method of data collection where missing
supplies were tracked in real time such as on a white board in the procedure area would have
given a more accurate picture of how often staff were missing supplies at the time they were
needed. This also would have provided a better way to equate time staff spent addressing missing
supplies during the work day.

Because of other recent changes to the supply system, limitations also include the
inability to distinguish the direct cause of outcomes. Kanban will add to these existing changes,
but it will be difficult to determine if continued improvements are related to it or a combination
of other smaller improvements in the system.

**MSN Essentials**

The CNL perspective, which is based on 9 essential competencies, was vital to
development of the protocol and demonstrated the value of integrating the CNL into
microsystem leadership. The CNL has a broad, advanced knowledge of nursing and healthcare,
but is also trained to implement process changes to improve outcomes within the system. For this
protocol specifically, the CNL was able to combine knowledge of microsystem supply chain
processes and team management skills to develop interventions to lower costs, improve
satisfaction, and overall streamline the supply process.

The clinical protocol was also intended to integrate the MSN/CNL program essential
competencies into its design. Many of the essentials were met through this project, with a few in
particular standing out as the most pertinent. For a full description of these competencies, see the
American Association of Colleges of Nursing’s Competencies and Curricular Expectations for

Essential II was heavily addressed throughout the project as it pertains to organizational
and systems leadership for quality improvement. Objectives for this essential include
demonstrating a working knowledge of the healthcare system and its parts, demonstrating business principles through strategic planning and budgeting, and collaborating with other healthcare professionals to implement and evaluate quality improvement activities. The MSN student did this by quickly learning the microsystem’s unique processes, participating in strategic and financial planning relating to the project, and consistently working with interdisciplinary team members to implement the planned intervention.

Essential V focuses on informatics and healthcare technologies and was also utilized frequently for the project. Key aspects of this essential are using technology to collect, analyze, and disseminate data and implementing the use of technologies for patient care including their cost effectiveness and appropriateness. Technology plays a large role in the supply chain system, as all supplies and PAR levels are tracked and ordered via a computer program. This technology was used by the MSN student on a daily basis to monitor discrepancies in supplies and to obtain outcomes. The MSN student also utilized technology to analyze information by creating graphs of outcomes and sharing this information.

Conclusion

The steps taken in preparation for the kanban intervention to the supply chain in the cardiac catheterization and interventional radiology lab have so far proven to be promising for improved outcomes and financial savings. Although this MSN project was not completed in entirety as planned prior to the end of the program, plans for its continuation and monitoring are in place in the department and the project will be carried out when funding is officially available. Overall, the proposed intervention will not only contribute to a Lean Six Sigma based efficient supply chain, but will also provide the opportunity to fill holes in the literature about the kanban two-bin system. Additionally, its prospected use in the cardiac catheterization and interventional
radiology lab has proven to be a successful MSN project with promising results to this point.
References


## Appendix A: Literature Review References

<table>
<thead>
<tr>
<th>Citation</th>
<th>Design/Method</th>
<th>Sample</th>
<th>Data Analysis/Results</th>
</tr>
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<tbody>
<tr>
<td><strong>State of the Supply Chain</strong></td>
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<tr>
<td>(Elmuti, Khoury, Omran, &amp; Abou-Zaid, 2013)</td>
<td>- 9 research questions identified by literature review - Likert scale survey with linear regression analysis - Qualitative interviews</td>
<td>-700 surveys sent to healthcare organizations in the U.S.; 210 usable returned (30% final response rate) - Interviews with 30 healthcare supply professionals from 20 organizations</td>
<td>- Regression analysis: positive relationship between supply chain activities (independent variable) and positive outcomes (dependent variable); supported by interviews - Supply chain management benefits organizational effectiveness - Challenges and facilitators identified</td>
</tr>
<tr>
<td>(Kim &amp; Kwon, 2015)</td>
<td>- Literature review</td>
<td>- 43 articles from the previous 10 years; divided into 4 main topics based on review</td>
<td>- Most studies are comparative between commercial and healthcare supply chain; more healthcare specific studies needed - Barriers and facilitators identified - Managerial implications and recommendations for long-term strategic planning</td>
</tr>
<tr>
<td><strong>Evidence for Lean</strong></td>
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<tr>
<td>(Aguilar-Escobar, Bourque, &amp; Godino-Gallego, 2015)</td>
<td>- Exploratory factor analysis and CAPTCHA analysis of anonymous 10-point, 12 question Likert scale survey</td>
<td>- 208 surveys returned from nurses and hospital staff of 26 departments in 2 hospitals within the AHVM healthcare system</td>
<td>- Overall satisfaction with kanban system at 6.94/10 - High rated items: fewer expired items, storage more orderly, less work for nurses - T-tests determined differences in kanban satisfaction according to department, seniority, and age of nurses</td>
</tr>
<tr>
<td>(Donnelly, Forester, &amp; Donnelly, 2016)</td>
<td>- Quality improvement project using</td>
<td>- Implementation of Lean kanban supply methods in a newly built children's</td>
<td>- System reliability = fill rate (100% minus stock-out rate)</td>
</tr>
<tr>
<td>Quantitative measures</td>
<td>Hospital; 2 radiology supply rooms (nodes) monitored for study (Imaging: 261 supply types, interventional radiology: 435)</td>
<td>Results after 2 years: - Imaging supply node: 98.08% fill rate - IR supply node: 98.7% fill rate - Financial savings reported</td>
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(Farrokhi, Gunther, Williams, & Blackmore, 2015) - Case-control study. Quantitative analysis pre and post Lean intervention to surgical trays: comparison of means, t-test, Wilcoxon two sample test

Virginia Mason Medical Center: 336 bed hospital with 24 ORs
- Intervention group: 885 MIS patients & 156 DBS patients
- Control group: 354 open spine surgery patients & 134 craniotomy patients
- January 1, 2009 to July 31, 2012

- Post intervention: 70-80% reduction in # of surgical instruments in standardized procedure trays
- Setup times decreased by 4.9 min (95% CI: 2.1, 7.7, p=.0015)
- Potential extrapolated cost savings of $2.8 million/year for this hospital

**Sustainability of Interventions**

(Poksinska, Swartling, & Drotz, 2013) - Case studies: interviews, shadowing and document review (strategies, charts, & instructions)

- In depth case study of 5 successful Lean organizations: 1 manufacturing company, 3 healthcare organizations and 1 municipal elderly care unit
- Interviews of managers and subordinates; 2-day shadowing of 4 managers; analysis of company documents related to Lean implementation

- Qualities of successful implementation:
  - Connection between Lean and transformational leadership
  - Increased employee responsibility through active participation and engagement; servant-leadership
  - Transition to self-managed teams

(Smith, Nachtmann, & Pohl, 2011) - Qualitative: expert interviews - Literature review

- Interviews with 14 healthcare supply chain professionals
  - 10 key papers reviewed
  - Author's previous 2009 quantitative

- Identified key factors influencing supply chain quality
  - Over 25 healthcare supply chain quality measures identified
Appendix B: The DMAIC Model

The DMAIC model consists of 5 steps (define, measure, analyze, improve, and control) for guiding process improvement with opportunity for modifying the project as needed (Borror, 2009). Elements of the cardiac catheterization/ interventional radiology department supply chain improvement project have been inserted into the diagram to demonstrate how DMAIC will guide implementation of the proposed intervention. The DMAIC model flowchart presented here is based on that of Borror (2009).
Appendix C: Protocol Gantt Chart

Two-bin Supply Protocol Timeline

<table>
<thead>
<tr>
<th>Task</th>
<th>Start Date</th>
<th># Days Required</th>
<th>Percent Complete</th>
</tr>
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<tbody>
<tr>
<td>Microsystem Assessment</td>
<td>6/1/16</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Identify Problem</td>
<td>8/1/16</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>Form team</td>
<td>8/15/16</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Kaizen phase 1 changes</td>
<td>9/1/16</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>Track supply outcomes</td>
<td>9/15/16</td>
<td>380</td>
<td>100</td>
</tr>
<tr>
<td>Dispatch tour of dept</td>
<td>1/14/17</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Meet with team; ID next steps</td>
<td>1/31/17</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Identify kanban barriers</td>
<td>1/31/17</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Quote for new carts &amp; cabinets</td>
<td>3/15/17</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Determine funding source</td>
<td>3/15/17</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Buy &amp; install catheter carts</td>
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</tr>
<tr>
<td>Buy &amp; install remote carts</td>
<td>7/1/17</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Buy &amp; install kanban cabinets</td>
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<td>45</td>
<td>0</td>
</tr>
<tr>
<td>Transition to kanban</td>
<td>9/15/17</td>
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<td>0</td>
</tr>
<tr>
<td>Staff training/education</td>
<td>9/15/17</td>
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## Appendix E: Data Collection Tool

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<th>Date</th>
<th>Loc</th>
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<th>Description</th>
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<th>Stic</th>
<th>Available amount</th>
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