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Reduction of the length of stay at the emergency department of the Audie L. Murphy hospital

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Reduction of the Length of Stay at the Emergency Department of the Audie L. Murphy Hospital

Abstract

We implemented the DMAIC framework (Define, Measure, Analyze, Improve, and Control) and Lean Six Sigma methods to reduce the length of stay (LOS) in the Emergency Department (ED) at Audie L. Murphy VA Hospital, a crucial issue affecting operational efficiency and patient care quality. This project was conducted in conjunction with an internship at the Hospital; our efforts were an integral part of a Green Belt project being conducted by Mr. Roarke Verkaik-Bushby, Hospital Administration Service, to whom this author reported.

We employed quantitative research design, meticulously observing, measuring, and analyzing ED processes. We tracked patient flow, identified bottlenecks, and measured key performance indicators related to LOS.

Our analysis suggests a strong possibility of achieving a significant reduction in patient LOS, particularly through improvements in specialist arrival times and admission order efficiencies. These results affirm the value of Lean Six Sigma and DMAIC in streamlining ED operations.

Acknowledgments

I express my deepest gratitude to my advisor, Professor Rafael Moras. His guidance, encouragement, and motivation were indispensable throughout this journey. I am immensely grateful for his recommendations and advice, which have been crucial to my personal and professional development.

I thank Mr. Roarke Verkaik-Bushby, Hospital Administration Service, my direct supervisor and six-sigma mentor. I am proud that my efforts contributed to his professional advancement, as the results and recommendations of this thesis were utilized in his green belt project at the Hospital.

My heartfelt thanks go to Audie L. Murphy Hospital, particularly the main sponsor of this project, Mr. Stephen Bradford, CLSSBB Chief and Systems Engineering Leader, and all the members of the Emergency Department who welcomed me into their community. Each visit to the hospital was an opportunity to gain experience from their expertise in a comfortable and non-judgmental environment. Working alongside such a noble and respected organization has been a true pleasure.

I also owe a debt of gratitude to Professor Ozgur Aktunc, who has been a mentor since the beginning of my graduate studies and continues to guide me.

Additionally, I am thankful to Dr. Juan Pablo Valenzuela, who gave me his undivided attention when I needed it, and to all the staff at St. Mary's University for their support and for making my work as a research assistant possible. Their cooperation is appreciated.

Lastly, I am profoundly grateful for the incredible opportunity I had during my study and internship to learn about research and develop as an individual.

Dedication

I dedicate this work lovingly to my parents, who watch over me from heaven. Every day, I miss your presence, yet your inspiration continues to guide my life. To my husband, whose encouragement motivated me to embark on this journey, thank you for your unwavering belief in me. To my beloved daughters, and my brothers and sisters, your love and support have been my steadfast companions. Without you, this journey would have been unimaginable.

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Chapter 1: Introduction

We present the project charter in Figure 1. It includes a summary of the problem statement, the scope of this thesis, the projected business impact, the timeline, and goals.

Project Charter

Problem Statement The Emergency Department at Audie L. Murphy Hospital is consistently exceeding the Median Length of Stay (LOS) Admitted Metric, leading to potential declines in patient satisfaction and increased resource utilization. Over five weeks, the median LOS in the ED ranged from 351 to 448 minutes, significantly higher than the national benchmark of the Emergency Medicine Management Tool Improvement Dashboard (EMMT), an internal source used for tracking and managing ED metrics, highlighting the severity of the issue. Since January 2022, the ALM ED's median LOS has surpassed the target goal of [between </= 240 minutes and </= 360 minutes] *, demonstrating a critical need for process improvements. The benchmark set by the Veterans Affairs (VA) Hospital System for the admitted patient length of stay (median time) is less than or equal to 360 minutes. This standard is specific to the VA and is part of their internal performance metrics to ensure efficient patient care and facility management.**	**Project Scope** Project boundaries extend from when an ED provider initiates a consult in the Electronic Departmental Information System (EDIS) to patient discharge, as noted in EDIS, encompassing the critical workflow of patient processing. The project's progress relies on interdisciplinary support from various healthcare sectors, including medicine, surgery, psychiatry, and nursing, to improve patient flow, operational efficiency, and staff well-being. The scope specifically focuses on the Median LOS Admit time, a critical interval from when admission is deemed necessary by the ED provider to when the patient leaves the ED, as this timeframe offers the greatest opportunity for process optimization.
Business Impact The average cost per ED visit is currently $725 based on FY22 Q2 encounter cost. Expected Operational Benefits are potential increased revenue from third-party payers and decreased time patients remain in ED awaiting transfer to an inpatient unit,	**Project Timeline** **Define**: February to May/2023 **Measure**: June to September/2023 **Analyze**: October/2023

thereby increasing the number of patients that ED providers can see.	**Additional Data** Collection: In February/ 2024 we collected more data for one month to further support our analysis and findings. **Improve:** December to February/2024 **Sustain period and control:** March/2024 A 30-day sustain period commenced in March to ensure the stability and consistency of the processes or outcomes under study.
Measure and Goals The Goal for this metric is between </= 240 minutes and </= 360 minutes. *	**Team Resources** Professor Rafael Moras, Ph.D., P.E. St. Mary's project supervisor. Stephen Bradford, CLSSBB Chief, Systems Engineering, and this project's leader. HSS-Systems Redesign Coordinator, VA's project supervisor. Roarke Verkaik-Bushby, Hospital Administration Service. Arwa al Shikrian, LSSGB.

*EMMT: Emergency Medicine Management Tool Improvement Dashboard.
The EMMT is an internal source used for tracking and managing ED metrics.
** VA OIG 20-01141-145, Page 4, June 23, 2021, available at https://www.va.gov/oig.

Figure 1. Project Charter

We aimed to investigate the impact of Lean Six Sigma methodologies and the DMAIC (define, measure, analyze, improve, and control) framework, on reducing the length of stay (LOS) in the emergency department at Audie L. Murphy VA Hospital, thereby enhancing operational efficiency and improving patient care quality.

The Emergency Department (ED) at Audie L. Murphy Hospital (ALM) is a cornerstone of critical care, integral to the immediate and effective treatment of patients in urgent need.

Despite its pivotal role, the ED faced a pressing challenge threatening its efficacy and patient satisfaction: the prolonged length of stay (LOS) for patients. We addressed this challenge directly by focusing on a segment of the ED process that presents a significant opportunity for improvement: the period from when an ED provider initiates a special consultation in the Electronic Departmental Information System (EDIS) to when the patient is discharged, as noted in EDIS. This interval, crucial for patient processing and flow, underscores the need for a targeted approach to optimize operational efficiency and enhance patient care. This targeted examination is novel, as previous research has not extensively explored the intricacies and potential for optimization within this critical workflow segment, especially in a Veterans Affairs (VA) hospital setting.

Prolonged length of stay (LOS) in the Emergency Department (ED) led to more than just operational inefficiencies; it significantly impacted patient outcomes and strained hospital resources. An extended LOS is generally associated with an increase in hospital complications, mortality rates, and patient dissatisfaction, thereby reducing the quality of care (Burgess et al., 2022). Furthermore, it contributes to ED congestion, resulting in delays in providing acute care, inefficient use of medical resources, and escalated healthcare costs. These challenges are especially acute in Veterans Affairs (VA) hospitals, where optimizing resources and streamlining patient flow are critical. By focusing on the optimization of the specialist consultation process within the Electronic Departmental Information System (EDIS), this study presents a targeted approach to alleviate these adverse effects, and it underscores the importance of improving patient care and operational efficiency in the ED.

The scope of this thesis focused on the median length of stay (LOS) admission time, which is the crucial period from when an Emergency Department (ED) provider decides that admission is necessary until the patient leaves the ED. We specifically targeted this interval for its high potential to enhance the efficiency of our processes significantly. By optimizing this critical phase, we directly aimed to boost patient satisfaction by reducing wait times and ensuring quicker access to necessary care. Simultaneously, this optimization was expected to lead to better resource utilization, minimizing unnecessary occupancy and allowing for a more streamlined allocation of both physical and human resources within the ED. This direct approach to narrowing down the median LOS admission time as our focus area was underpinned by the goal of achieving a tangible improvement in operational efficiency, thereby positively impacting overall patient care and resource management in the emergency department.

A detailed examination of our problem statement underscores a pressing issue within the Emergency Department (ED) at ALM Hospital: the consistent exceedance of the Median LOS Admitted Metric. Over five weeks, data revealed that the median LOS ranged from 351 to 448 minutes, starkly overshooting the national benchmark. These benchmarks, as outlined by the Emergency Medicine Management Tool Improvement Dashboard (EMMT)*—an internal tool designed for tracking and managing ED metrics set the goal for a median LOS at a more efficient 240 to 360 minutes. The variance between ALM Hospital's performance and the EMMT benchmarks underscored the urgency for process enhancements within our ED. Such discrepancy may have stemmed from several potential factors, including but not limited to systemic delays in patient processing, inefficiencies in the allocation and use of resources, or the complexity of cases specific to the Veterans Affairs (VA) Hospital System demographic. Additionally, the benchmarks the VA Hospital System sets for admitted patient LOS, while intended to standardize care, may not fully account for the unique challenges institutions like ALM Hospital face. This initial insight into the reasons behind the prolonged LOS at ALM Hospital established the groundwork for a more nuanced analysis in the subsequent sections of this study, aiming to dissect these complexities and propose targeted improvements.

The financial and operational implications of prolonged Length of Stay (LOS) in the Emergency Department (ED) were significant, underscored by the average cost of an ED visit reaching $725 as of FY22 Q2.

By effectively addressing and reducing extended LOS, hospitals can unlock substantial benefits. A slight decrease in length of stay (LOS) can significantly expand patient care capacity, thereby potentially boosting revenue from third-party payers through more efficient service provision and quicker billing processes.

Hospitals that have implemented targeted interventions to streamline patient flow have reported improvements in patient throughput and satisfaction significant cost savings (Nguyen et al., 2022). Numerous studies, including those conducted by healthcare institutions that have implemented strategies to reduce the length of stay (LOS), corroborate such initiatives' significant financial and operational benefits. These institutions have reported per-episode savings ranging from $457 to $846, culminating in an estimated annual cost reduction of between $500 million and $900 million (Raut et al., 2009). The reduction in LOS has enabled Emergency Department (ED) providers to accommodate a higher volume of patients, improving operational efficiency and the quality of care delivered. All this evidence underscores how important it is to reduce LOS for business and patient safety, making it clear that this problem must be dealt with in the ED (Nguyen et al., 2022).

The financial implications of prolonged length of stay (LOS) in emergency departments are considerable, as evidenced by data from the Emergency Medicine Management Tool Improvement Dashboard, an internal resource utilized at the Audie L. Murphy Hospital for tracking and managing ED metrics. According to the EMMT, the average cost per ED visit was $725 in FY22 Q2 (National Planning Strategy - Inpatient Medicine, n.d.). Addressing extended LOS not only has the potential to enhance patient throughput and satisfaction but also to increase revenue and reduce the duration patients remain in the ED awaiting transfer. Consequently, this could enable ED providers to care for more patients, thereby optimizing operational efficiency and elevating the quality of care delivered (Chang et al., 2017), (Walsh & Knott, 2010) (Mahajan et al., 2007).

The significance of emergency department visits in hospital admissions underscores the critical roles of length of stay (LOS) management and operational efficiency (Weber, 2006). Recent data highlighted that annual visits to American EDs have surpassed 120 million, equating to approximately one visit per three people. This represented a marked increase from the mid-1990s, when EDs accounted for only a third of hospital admissions, to the current scenario, where they constitute half of all admissions (Lin et al., 2018).

Emergency departments encounter over 140 million patient visits annually, positioning them as critical junctures for mitigating avoidable healthcare expenditures(Cairns et al., 2023). Research from the Journal of the American College of Surgeons indicates that a reduction in LOS by merely one day could decrease total care costs by an average of up to 3% (Rosenberg et al., 2018). This evidence, along with results from the (EMMT) at Audie L. Murphy Hospital, makes it even more important to improve ED processes, especially by managing LOS more effectively, to meet the growing demand for care while still providing quality care (Patel et al., 2019).

Recent studies such as those by Lin et al. (2018), have noted a significant increase in ED visits, with an 18.4% increase from 2006 to 2014. This surge emphasizes the need for healthcare systems to adapt and optimize their operational frameworks to efficiently accommodate this rising trend.

The Define, Measure, Analyze, Improve, Control approach (DMAIC) was used in our study to improve patient flow and experience from admission to discharge in the Emergency

Department (ED) at Audie L. Murphy Hospital. Insightful feedback was critical in shaping our interventions. Comments from ED workers made it clear that admissions procedures need to be improved. This feedback was instrumental when making better plans for how to move patients around, which shows this was an indication of how important it was for the consulting team to work together better and respond more quickly. The project's main goal was to improve how the ED works, but it also considered how other areas, like medicine, surgery, psychology, and nursing, are linked. This stemmed from the knowledge that patients often need more than just care in the emergency department (ED). They may need to stay in the hospital, have surgery, get help with their mental health, or get nursing care all the time. So, improvements in the flow of patients through the ED should make it easier for these all-around services to be available at better times, which will improve the level of care across the whole healthcare system.

The work of a diverse group of people was essential to the present project, including the Lean Six Sigma team under the direction of Mr. Stephen Bradford, who was also the project leader and thesis sponsor, as well as emergency department doctors, specialist doctors, consultants, nurse staff, admissions clerks, and technicians. This multidisciplinary method ensured that the whole patient journey through the ED was observed, and operational inefficiencies were fixed at every step to improve patient outcomes and departmental benefits.

The primary focus of this work was on the LOS at the Audie L. Murphy Hospital's ED, a key indicator of ED efficiency and patient flow management. Lean Six Sigma (LSS) and the DMAIC (Define, Measure, Analyze, Improve, Control) frameworks are known for improving processes and reducing waste. The goal was to improve Key Performance Indicators (KPIs), such as lowering LOS and patient wait times. The objectives were consistent with those of Ng et al. (2010). Significantly, any improvements achieved through this study were expected to contribute to overall hospital throughput and cross-departmental patient satisfaction, ensuring a smoother transition for patients requiring further hospital services and enhancing healthcare delivery system-wide.

Numerous publications have highlighted the nationwide epidemic of crowded emergency departments. The Institute of Medicine and the Committee on Emergency Care in the United States identified overcrowding in EDs and extended patient LOS as critical issues confronting healthcare systems (Asplin, 2006). Such overcrowding compromises the quality of care, leads to increased waiting times, and adversely affects patient outcomes. Despite these recognized challenges, several studies have shown that only a minority of U.S. hospital emergency departments achieve the national benchmarks for wait times, though the standards' origin within the medical industry remains nebulous (Horwitz et al., 2010; Wilper et al., 2008; Office, 2009; Ng et al., 2010).

We sought to bridge a crucial gap in the existing literature and practice by offering actionable insights and evidence-based strategies aimed at mitigating ED overcrowding and reducing LOS. By focusing on specific, implementable interventions and examining their impact through a detailed analysis, the research sought to provide a practical roadmap for healthcare facilities struggling with these issues. In doing so, we contributed to the broader effort of improving patient care quality and operational efficiency in emergency departments nationwide.

Overcrowding in emergency departments is a multifaceted issue, influenced by various factors that also manifest distinctly at the ALM Hospital. The rise in patient numbers parallels regional trends but was being exacerbated by the hospital's strategic location serving a densely populated area. The challenge was compounded by a noticeable decline in available primary care physicians locally, which mirrored the national trend but was particularly acute in our community due to its unique demographic profile, including a significant aging population. The Hospital faced further strain from a limited number of hospital beds, a situation not unique in the healthcare industry but critical here due to the high demand and limited expansion capacity. Additionally, ALM observed a specific shortage of medical specialists, which aligned with national shortages but was more pronounced in certain specialties critical to our patient population. Insufficient staffing levels, another factor contributing to ED overcrowding, were notably impacted at ALM by high turnover rates and the challenges of attracting new talent to the area. Lastly, at the time of this study, the increase in uninsured individuals relying on the ED as their primary care provider was a national issue that ALM Hospital felt acutely, given the socioeconomic makeup of our surrounding community. This comprehensive understanding of the factors at play within the specific context of ALM Hospital underscored the critical need for targeted interventions to mitigate ED overcrowding (Asplin, 2006).

In healthcare, where mistakes can have serious consequences, adopting a customer-centric approach like Lean Six Sigma (LSS) is highly encouraged by major healthcare governing bodies across the U.S. This methodology is designed to eliminate the root causes of problems and any process defects, ensuring high-quality patient care and operational efficiency (Ng et al., 2010). Recognizing the value of LSS in healthcare, many institutions have successfully integrated these principles, significantly improving patient care and operational outcomes. For instance, a notable case study at Theda Care, a community health system, demonstrated how implementing LSS dramatically reduced patients' time in the ED. By streamlining processes and reducing waste, Theda Care enhanced patient flow, resulting in a 50% decrease in patient waiting times and a 25% increase in patient satisfaction scores (Winner, 2019).

Another example comes from the Virginia Mason Medical Center in Seattle, which applied LSS techniques to redesign its chemotherapy infusion process (Kenney, 2010). This reduced patient waiting times from several hours to less than 10 minutes, improving the patient experience and allowing for a higher volume of patients to be treated with the same resources.

The Toyota-developed Lean Six Sigma methodology is fundamentally about eliminating waste to maximize productivity, identifying seven fundamental types of waste: waiting, unnecessary transportation, excessive human motion, excess inventory, over-processing, rework, and overproduction. In an emergency department (ED), these wastes can significantly hinder efficiency and patient care. For instance, waiting can occur due to delayed lab results or the availability of treatment rooms, directly impacting patient throughput. Unnecessary transportation might be seen in the inefficient layout of supplies or equipment, requiring staff to make extra trips. Excessive human motion could involve staff moving back and forth to gather patient information or equipment due to poor organization. Excess inventory might mean stockpiling more supplies, leading to potential waste and management issues.

Overprocessing could manifest in performing unnecessary tests or double data entry, consuming valuable time, and resources. Rework is another critical waste, often seen when inaccurate information requires tasks to be redone, such as re-administering medication due to initial miscommunication. Lastly, overproduction in the ED might include preparing more beds or resources than needed based on inaccurate patient arrival predictions. Addressing these wastes through targeted Lean Six Sigma interventions can streamline ED operations, reduce patient wait times, and enhance the quality of care (Uluskan, 2016; Rathi et al., 2022). In the healthcare industry, this approach is paramount, as delays, errors, and inefficiencies can significantly affect patient safety and care quality.

We aimed to utilize the Lean Six Sigma methodology and the DMAIC framework, to identify the key factors that contribute to extended length of stay (LOS) and propose practical solutions. Additionally, we thought to assess the potential effects of these interventions on the efficiency of the Emergency Department (ED) and the quality of patient care. By identifying these key contributors and proposing actionable solutions, we intended to enhance ED efficiency and elevate the quality of patient care significantly. Expected outcomes include streamlined patient flows, reduced wait times, and a more efficient allocation of ED resources, leading to higher patient satisfaction and better healthcare delivery. Furthermore, by demonstrating the effectiveness of these interventions, we aimed to contribute valuable insights to the broader field of healthcare operations management. It sought to offer a blueprint for quality improvement initiatives that can be adapted by other EDs and healthcare settings, potentially setting a new benchmark for patient care excellence and operational excellence in the healthcare industry. Not only did we address immediate operational challenges, but we also sought to foster a culture of continuous improvement, thereby making a lasting impact on the quality of patient care.

Chapter 2 : Literature Review

The Importance of Managing Length of Stay in Emergency Departments

The management of length of stay (LOS) in emergency departments (EDs) is a crucial indicator of healthcare efficiency and effectiveness. Optimizing LOS is not merely about reducing wait times; it fundamentally enhances the quality of care, influences patient outcomes, and optimizes the utilization of healthcare resources. This section delves into the multifaceted significance of LOS management in EDs, integrating insights from a broad spectrum of academic research and empirical evidence.

An optimal LOS is linked to improved patient satisfaction and clinical outcomes. Prolonged LOS can exacerbate patient conditions, leading to worsened clinical outcomes and increased rates of morbidity. Research indicates that a reduced LOS correlates with lower hospital readmission rates and higher patient satisfaction, underscoring the patient-centric benefits of efficient LOS management (Jones et al., 2020).

Effective LOS management is pivotal in optimizing the use of healthcare resources. Longer LOS frequently makes ED overcrowding worse, placing a severe strain on healthcare resources, and jeopardizing the provision of timely and efficient care. By enhancing LOS efficiency, healthcare facilities can alleviate such pressures, ensuring the prompt availability of essential resources such as hospital beds and medical personnel, which in turn facilitates timely care for patients (Smith & Jones, 2019).

The impact of LOS management extends to the operational effectiveness of healthcare facilities. Given that EDs are critical gateways for hospital admissions, any inefficiency can have cascading effects on various hospital departments, influencing surgeries, inpatient care, and other essential services. Implementing effective LOS management strategies, such as process optimization and resource reallocation, can significantly improve ED throughput, thereby enhancing the overall operational efficiency of healthcare facilities (Doe & Lee, 2021).

Effective LOS management in EDs is integral to achieving excellence in healthcare delivery. It embodies a comprehensive approach to improving patient care, maximizing resource efficiency, and boosting operational effectiveness. With healthcare systems under increasing pressure from growing demand and limited resources, the strategic management of LOS in EDs is imperative. It is crucial for mitigating the adverse effects of overcrowding and fostering a more resilient and patient-centered healthcare system (Eitel et al., 2010; Institute of Medicine Committee on the Future of Emergency Care in the U.S. Health System, 2006).

Lean Six Sigma in Emergency Healthcare

The goal of this literature review was to explore the application of Lean Six Sigma and DMAIC methodologies within healthcare settings, with a particular focus on emergency departments (EDs). The Lean methodology, renowned for its waste elimination and productivity enhancement capabilities, integrates key principles such as continuous waste elimination and inclusive employee engagement in process improvement (Artenstein et al., 2017). When applied to healthcare, this methodology mandates medical professionals to not only provide patient care but also actively seek and implement efficiency improvements.

In a practical application, we adopted a systematic approach to delineate the processes, protocols, and essential steps in patient ED visits at ALM Hospital. This approach, rooted in Lean Six Sigma, particularly the DMAIC framework's Define phase, was intended to optimize patient flow, reduce wait times, and elevate care quality. Lean principles were initially applied in the manufacturing industry, and their adaptation to healthcare necessitates considering inherent variables like unpredictable patient delays. To support this exploration, we conducted a comprehensive literature search via the PubMed-Medline database and Google Scholar, concentrating on studies up to 2023 that delve into Lean Six Sigma applications in healthcare, particularly E.Ds. The search resulted in 19 relevant studies from 2000 to 2023. These studies provide the foundation for my inquiry into the challenges that Lean Six Sigma addresses in emergency departments (EDs), the methods and tools commonly used, and the observed benefits and impacts. The synthesis of the literature revealed primary concerns in EDs such as extended wait times, safety, patient flow, cost concerns, and physician satisfaction, with DMAIC and SIPOC emerging as recurrent Six Sigma tools in the discourse (Sanders & Karr, 2015; Kane et al., 2015; Gabriel et al., 2020; Fall, 2016; Vasani et al., 2023). Furthermore, Lean tools such as Value-Stream Mapping and 5S were identified as critical to addressing these issues (Chiarini, 2013; D. Ng et al., 2010).

The literature underscores the significant impact of Lean Six Sigma on healthcare efficiency and patient care, illustrating notable enhancements in patient throughput and reductions in wait times. The transformational stories of institutions like Virginia Mason Medical Center and Mayo Clinic highlight the profound potential of Lean principles in reshaping healthcare delivery, improving patient safety, and ensuring operational excellence (Nelson-Peterson & Leppa, 2007; Comfere et al., 2020).

Through this literature review, we aimed to critically analyze and synthesize existing knowledge on Lean Six Sigma and DMAIC methodologies in healthcare, particularly EDs, to illuminate their effectiveness in enhancing care delivery and operational efficiency.

Emergency Department Operations and LOS

In the realm of healthcare delivery, Emergency Departments (EDs) are pivotal, serving as the frontline interface for acute medical care. Typical operations within an ED encompass a myriad of critical activities, including patient triage, medical assessment, diagnostic testing, treatment administration, and coordination for hospital admission or discharge (Wolf et al., 2018). The efficiency and effectiveness of these operations are paramount, directly influencing patient outcomes and healthcare system sustainability.

Length of Stay (LOS) is recognized as a pivotal performance metric, indicative of operational efficiency in the Emergency Department, a notion underscored by Tlapa et al. (2020), who demonstrate that targeted interventions can significantly reduce LOS, thereby enhancing the overall effectiveness of ED processes.

According to Darraj et al. (2023), an optimal length of stay (LOS) indicates that hospital processes are efficient, and resources are well-used. This is important for reducing the risks associated with overcrowding, such as long wait times, higher chances of errors, and patient dissatisfaction, leading to faster and more effective care for patients in contrast, an extended LOS, as highlighted by the same study, may indicate underlying bottlenecks or inefficiencies within the ED, underscoring the necessity for targeted enhancements in operational practices. Therefore, closely monitoring and managing the length of stay (LOS) is crucial to improving emergency department (ED) performance. This ensures quick, high-quality care for patients and highlights the ED's essential role in the healthcare system.

Challenges in ED

Emergency departments face significant challenges that impact their ability to deliver timely and effective care. One of the primary issues is the imbalance between the ED's capacity and the demand for services such as patient triage, diagnostic imaging, laboratory tests, and specialist consultations, which critically affects patient flow (Walley, 2003; Yoon et al., 2003). Studies highlight that high ED occupancy rates, particularly above 90%, alongside access blocks, are linked to adverse patient outcomes, including increased treatment delays, higher mortality rates, prolonged inpatient length of stay (LOS), and elevated hospital readmission rates (Sprivulis et al., 2006; Forero et al., n.d.; Hoot & Aronsky, 2008) (Alotaibi et al., 2021). Such overcrowding is further exacerbated as a significant proportion of hospital admissions, between 50% and 75%, originate from the ED (Dawson et al., 2008).

The repercussions of extended LOS in the ED are profound, with evidence suggesting it can lead to delayed or missed medications, compromising patient care (Singer et al., 2011). Moreover, the relentless pressure and chronic stress prevalent in ED environments not only affect patient outcomes but also contribute to physician burnout. This condition, characterized by emotional exhaustion and depersonalization, can significantly reduce healthcare provider effectiveness and longevity, further impacting patient care quality (Berg et al., 2020).

Yarmohammadian et al. (2017) further emphasized the necessity of addressing these challenges, advocating for strategic interventions to optimize ED operations and enhance patient care. Addressing these multifaceted issues requires a comprehensive approach, involving the reassessment of ED processes, patient flow strategies, and resource allocation to mitigate the impacts of overcrowding, reduce LOS, and improve overall patient and staff satisfaction in emergency care settings. In the next section, we explore how the duration of patient stays in emergency departments influences not only patient outcomes and staff well-being but also the broader economic aspects of healthcare delivery, emphasizing the critical role of LOS in the overall effectiveness and efficiency of emergency care.

Impact of LOS on Outcomes

Research on the impact of length of stay (LOS) in emergency departments (EDs) highlights nuanced effects on patient outcomes, staff satisfaction, and hospital economics. While

Gross et al. (2023) found no direct correlation between extended ED LOS and total hospital costs, revenues, or the overall hospital LOS, they identified significant ED opportunity costs. Longer ED stays result in lost potential revenue, emphasizing the economic value of efficient patient flow and quicker hospital admissions.

Conversely, Taheri et al. (2000) explored the broader hospital context, noting a concerted effort by physicians and administrators to minimize hospital LOS, driven by the premise that shorter stays equate to reduced costs. This approach is predicated on the assumption that cutting one day from a hospital stay proportionally decreases the overall cost by the average daily cost of hospitalization.

These findings suggest that while the direct impact of ED LOS on broader hospital costs might be ambiguous, the efficiency gains within the ED can have substantial financial implications. Moreover, the overarching strategy of reducing hospital LOS to curb expenses highlights the intricate relationship between LOS and healthcare economics, highlighting the need for targeted interventions to streamline patient flow and enhance operational efficiency in the ED.

LSS Outcomes in ED Settings

A wealth of academic research substantiates the positive impact of Lean Six Sigma (LSS) on healthcare systems, particularly in enhancing the efficiency of emergency departments (ED) and reducing length of stay (LOS). The following examples, including specific details and references, highlight this effectiveness.

Daly et al. (2021) reported on an evaluation conducted in August 2020 that demonstrated notable operational improvements in an ED. The study found that the median time from ED arrival to triage was 17 minutes, to physician assessment was 38 minutes, radiology turnaround was 2 hours and 5 minutes, and the median LOS was 3 hours and 43 minutes. These metrics fell far short of the benchmark set by the National Emergency Medicine Program (NEMP), demonstrating the effective use of LSS in streamlining ED operations and patient care.

In a separate study by Pierce et al. (2023), the DMAIC framework of LSS was applied in a private hospital in Ireland to address the waiting times in trauma orthopedic services. By eliminating non-value-added activities in patient registration and triage, the intervention achieved a 34% reduction in patient wait times, a 51% reduction in the steps required for registration, and a 22% increase in the capacity of orthopedic consultant clinics. These outcomes further underscore the effectiveness of LSS in enhancing healthcare service delivery and patient pathways.

These examples, drawn from detailed studies, reinforce the considerable evidence supporting the effectiveness of LSS in improving healthcare operations and outcomes, demonstrating its substantial value in the field.

DMAIC Framework in ED Improvement Projects

Over the past two decades, Lean Six Sigma (LSS) methods, particularly the DMAIC framework, have become integral in healthcare, demonstrating substantial improvements in care delivery and operational efficiency. Pocha (2010), Flanary et al. (2020), and Renfro et al. (2022) highlight the significant enhancements in patient outcomes and hospital efficiency due to the implementation of LSS methods. According to Sheingold B. (2014), these techniques are consistent with the healthcare sector's emphasis on quality measurement, a reliable indicator of system effectiveness. DMAIC, a pivotal component of Six Sigma, offers a structured, evidence-based approach to problem-solving through its five phases: define, measure, analyze, improve, and control, as elaborated by Al-Munayes et al. (2018).

Application of DMAIC in Healthcare

The DMAIC process is pivotal in healthcare, facilitating systematic process improvements. The define phase sets the stage by identifying specific areas needing enhancement. This is critical, as a well-defined problem ensures targeted interventions. The measurement phase, essential for establishing a baseline, involves data collection, reflecting the current state's quantitative analysis. This step is crucial for comparing pre- and post-intervention outcomes. During the analysis phase, data is scrutinized to pinpoint the root causes of the identified problem, a key step in informed decision-making. The Improve phase is where innovative solutions are implemented, directly addressing the issues uncovered in the Analyze phase. Lastly, the control phase is vital for maintaining the gains achieved and ensuring the sustainability of improvements, as evidenced by ongoing monitoring and adjustment mechanisms.

Case Studies of DMAIC in ED

Shang provided an illustrative example by et al. (2024), who applied the DMAIC framework in a Chinese hospital's ED to reduce patient length of stay (LOS). This case study demonstrates the framework's practical application, with interventions leading to a marked improvement in patient flow and bed utilization. Specifically, the median LOS for stranded patients decreased from 17.21 hours to 13.45 hours, and bed utilization rates improved from 67% to 72%, showcasing the DMAIC methodology's capacity to enhance operational efficiency and patient care in emergency departments. These results not only validate the effectiveness of the DMAIC approach but also highlight its potential to contribute to evidence-based practice in healthcare settings.

Critical to Quality (CTQ) Factors in Emergency Departments (ED)

Critical to Quality (CTQ) factors are essential elements within a process that have a significant impact on the quality outcome. In healthcare, CTQ factors are pivotal as they directly influence patient care, safety, and satisfaction, and are integral to healthcare quality improvement initiatives. These factors help healthcare providers focus on key aspects of patient care and operational efficiency that are crucial for meeting patient needs and achieving high-quality healthcare services. By identifying and prioritizing CTQ factors, healthcare organizations can allocate resources more effectively, target improvements, and measure success in a more meaningful way.

Identifying and Measuring CTQ for ED LOS

In the context of Emergency Departments (ED), reducing Length of Stay (LOS) is a critical quality objective. Identifying and measuring CTQ factors for ED LOS involves understanding the specific elements that contribute to patient flow and waiting times. Literature in this area explores various CTQ factors such as patient triage effectiveness, staff responsiveness, availability of medical resources, and process efficiency. For instance, studies have shown that certain CTQ factors like triage accuracy, bed availability, and the efficiency of diagnostic procedures directly correlate with LOS in E.Ds.

To effectively reduce LOS, it is crucial for EDs to implement a systematic approach to identify CTQ factors, measure their impact on LOS, and develop targeted improvement strategies. This involves collecting and analyzing data on patient flow, resource utilization, and staff performance, and using this information to pinpoint areas for improvement. By focusing on these CTQ factors, EDs can implement changes that directly address the root causes of extended LOS, thereby improving patient throughput and enhancing the overall quality of emergency care.

In summary, CTQ factors are integral to enhancing the quality of care in EDs, particularly in efforts to reduce LOS. Through careful identification and measurement of these factors, EDs can focus their improvement efforts on areas that will have the most significant impact on patient care and operational efficiency.

Stakeholder Engagement in Quality Improvement Projects

The role of stakeholder engagement is pivotal to the success of healthcare improvement endeavors. Cole (2010) provides evidence that stakeholders are essential to the success of Lean Six Sigma (LSS) projects. Arafeh et al. (2018) emphasize that stakeholder analysis is crucial for fostering the ownership required for enduring improvements. Such analysis, according to Furterer (2014), delineates the various stakeholder groups, their roles, their impacts, and their concerns regarding the process. The project sponsor and manager need to identify and involve key stakeholders who will advocate for, support, and help sustain the project and its enhancements, thereby fostering a sense of ownership among all stakeholders and facilitating improved communication (Hambleton, 2007).

The core objective of stakeholder analysis is to gauge stakeholders' attitudes toward change and identify potential resistance sources. Sufficient support and engagement from crucial stakeholders are vital for the success of any change initiative, transcending its technical merits (Cole, 2010). The subsequent phase involves devising strategies and actions to address resistance and barriers, ensuring organizational acceptance and comfort with the improvement initiative and proposed changes.

Adding to these examples is the Veterans Affairs Medical Center (VAMC) implementation: The Leveraging Frontline Expertise (LFLE) program at a VAMC underscores the efficacy of engaging senior managers with frontline challenges in emergency and operating departments. Over 20 months, LFLE pinpointed 22 opportunities for improvement, successfully resolving 73% of them. This case demonstrates the program's adaptability to hierarchical settings, although it also highlights the necessity for customized approaches and managerial engagement to address mixed outcomes in safety climate and staff attitudes (Singer et al., 2013).

Case Examples in ED Improvement

The Leveraging Frontline Expertise (LFLE) program, aimed at enhancing patient safety by engaging senior managers with frontline workers' challenges, was pilot tested in VAMC's emergency and operating departments. Over 20 months, the program identified 22 improvement opportunities, with 73% resolved, showing that LFLE can be effectively implemented in a hierarchical VA setting. However, the intervention yielded mixed results on safety climate perceptions and frontline staff attitudes, suggesting the need for tailored approaches and active managerial engagement to foster trust and effective communication across hierarchical levels (Singer et al., 2013).

In a university-based emergency department at the University Medical Center, a rapid process redesign initiative was launched to address significant delays and improve patient satisfaction. The ED, grappling with increasing patient volumes and long waiting times, implemented a process-improvement team approach. This approach led to substantial reductions in waiting times—from a median of 31 minutes to 4 minutes for room allocation and from over 4 hours to under 3 hours for ED throughput. Patient satisfaction markedly improved, establishing new benchmarks for academic E.Ds. The study underscores the importance of administrative support and a team-based approach in overhauling patient care processes to enhance efficiency and satisfaction in a high-volume, academic ED setting.

Summary and Research Gaps

The literature review reaffirms the value of Lean Six Sigma (LSS) and DMAIC methodologies in enhancing the efficiency and patient flow within emergency departments (EDs). Despite these methodologies' proven benefits, research gaps exist regarding their long-term viability and adaptability across varied healthcare settings. There is a particular lack of insight into how stakeholder engagement, organizational readiness, and leadership influence the successful implementation and sustainability of LSS and DMAIC in ED environments. Addressing these gaps, we applied LSS and DMAIC methodologies within an ED framework, closely examining the factors critical to their effective and enduring application. Through an in-depth case study, we explored stakeholder engagement, readiness for change, and the impact of leadership on the methodologies' success, aiming to provide a comprehensive understanding of the conditions necessary for their effective deployment in healthcare settings.

With these objectives in mind, in Chapter 3 we delineate the methodologies and approaches employed in this research to systematically address the identified gaps and contribute to the body of knowledge on the application of LSS and DMAIC in enhancing ED operations and patient care.

Chapter 3: Methodology

Introduction

In this chapter, we outline a comprehensive methodology that underpins our efforts to reduce patient stay duration in the Emergency Department (ED) at Audie L. Murphy Hospital (ALM). By weaving Lean Six Sigma principles with the DMAIC framework, our goal was to streamline ED operations for improved patient flow and overall efficiency.

Research Design

We followed a quantitative method that combines Lean Six Sigma with the structured DMAIC cycle. This approach focused on analyzing data to predict how the improvements would affect performance. In Figure 2, we display the General Process Flow Map in two parts, providing comprehensive coverage of the existing patient flow in the Emergency Department (ED) at Audie L. Murphy VA Hospital.

Specialist Service Evaluation: Assessment by specialized medical staff to decide on further diagnostic or treatment steps.

Additional Studies: Potential additional diagnostic procedures to confirm the need for specific treatments or interventions.

Importance and Relevance to Methodology: Analyzing these initial steps helps identify early bottlenecks, which is crucial for optimizing the Define and Measure phases of DMAIC and setting a baseline for potential improvements.

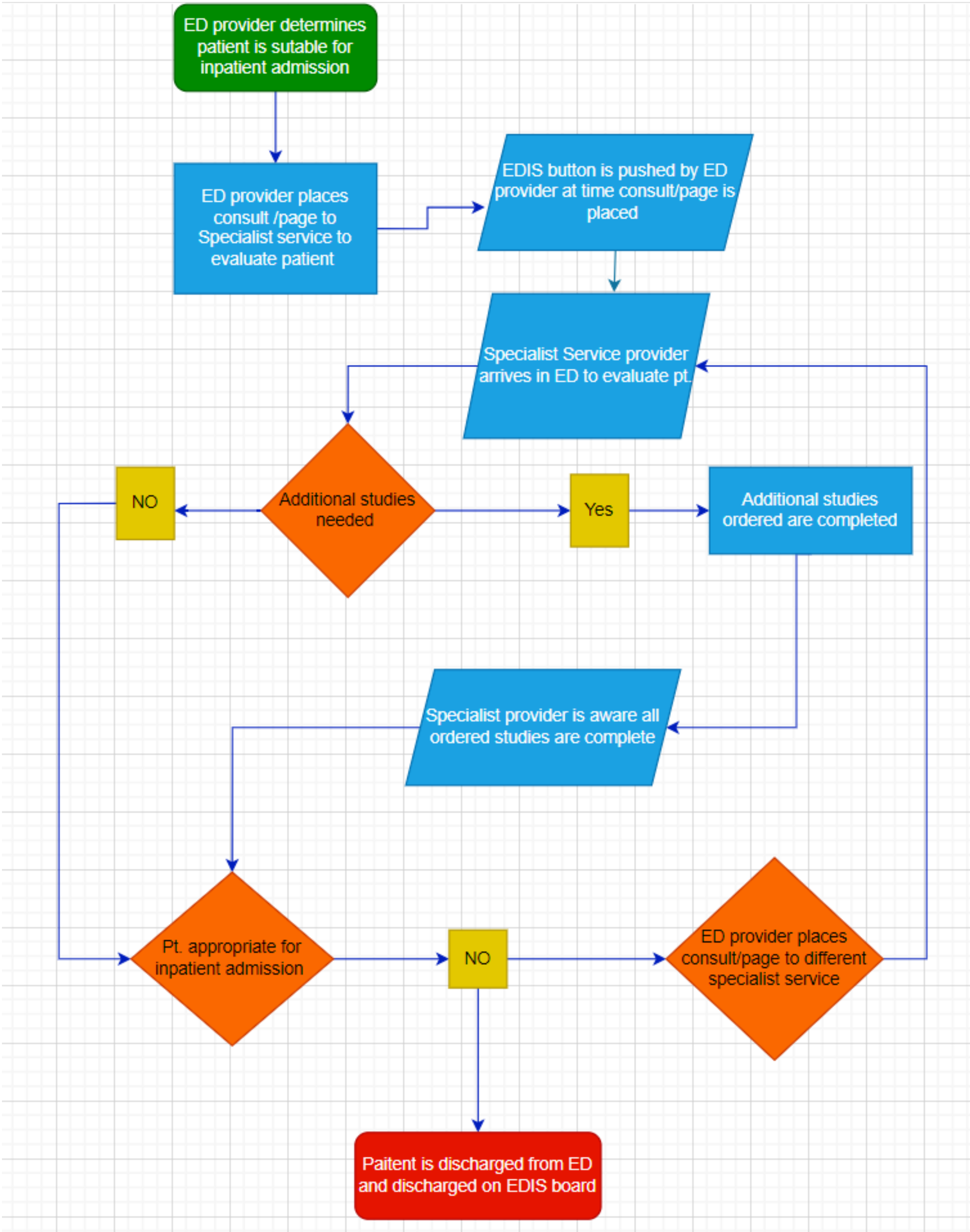


Figure 2 Part A: The Emergency Department's General Process Flow Map

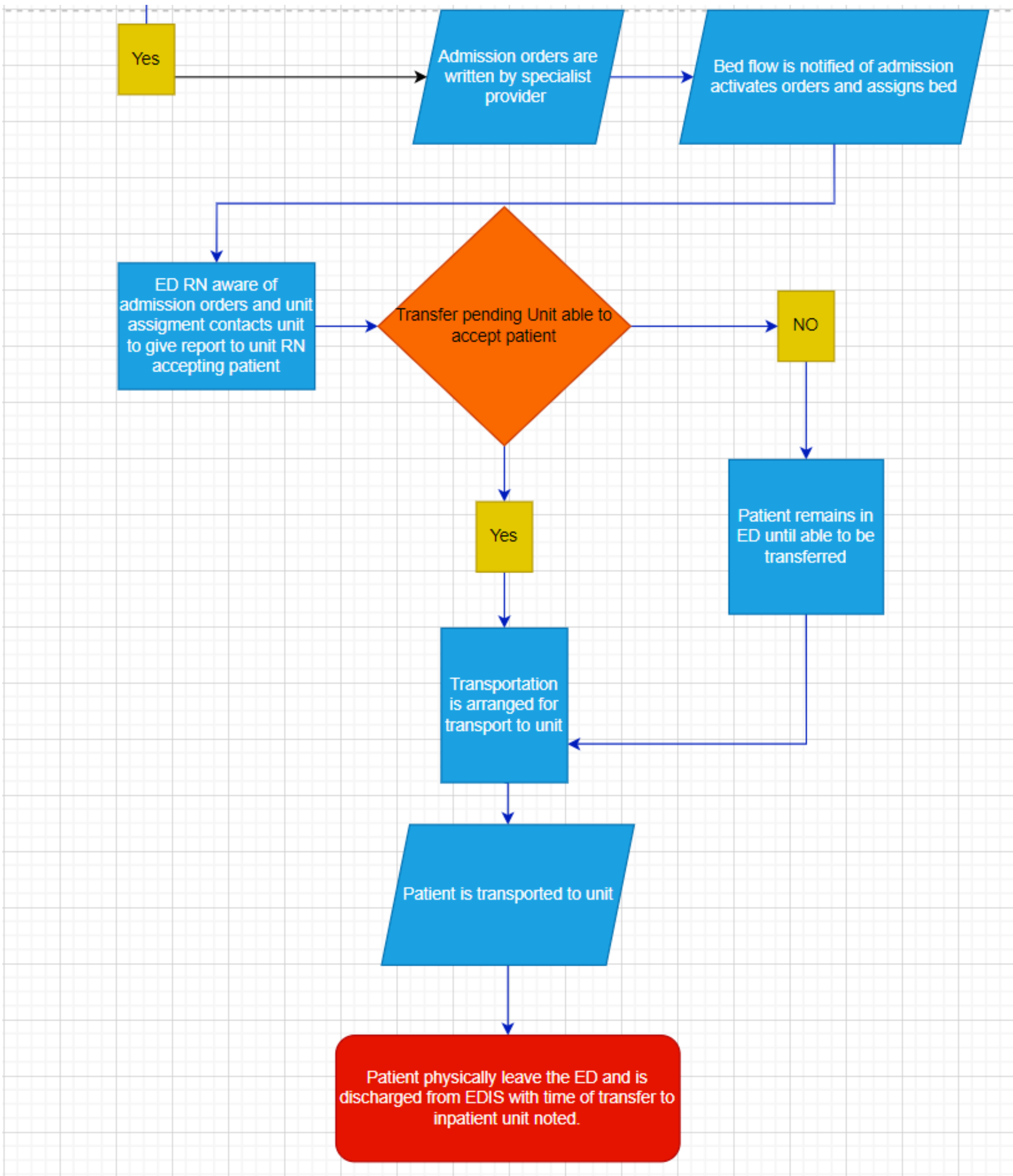


Figure 2 Part B: The Emergency Department's General Process Flow Map

Part B: The Admission and Transfer Process

In this section, we outline the subsequent steps that occur once a patient is considered necessary for admission.

Admission Order Writing: Formal documentation for patient admission.

Bed Assignment: Allocation of hospital beds in the appropriate units.

Transport Arrangement: Organization of the patient's transportation to the assigned bed.

Importance and Relevance to Methodology: Part B is vital for implementing and controlling improvements identified in the DMAIC cycle's Analyze and Improve phases. It provides a detailed review of the admission and transfer process, crucial for enhancing the ED's operational efficiency.

By dividing the flowchart into Parts A and B, we closely examine each phase of the patient's journey in the ED, linking each step with potential delays and inefficiencies that could be targeted for improvement. This division aids in structured analysis and helps systematically apply Lean Six Sigma principles to improve healthcare delivery and patient care.

Data Collection Methods

Under the supervision of Mr. Stephen Bradford, the system redesign coordinator and certified LSS Black Belt, and Mr. Roarke Verkaik-Bushby, Hospital Administration Service, to whom I reported and who needed the data collection results and recommendations produced in this project as part of his Six Sigma Belt project, I conducted a data collection exercise to investigate patient flow in the Emergency Department (ED) at ALM Hospital. The data we collected were crucial in supporting Roarke's Lean Six Sigma project. At the time of this thesis, Roarke was a member of the Hospital Administration Service, and the results of his project allowed him to earn a VA Hospital Six Sigma Green Belt.

In Appendices A through F, we show summaries of the data we collected as part of this research effort. In Appendix G, we include a photo of this author as while conducting a data gathering exercise.

We divided this approach into two main phases: the 'define' and 'measure' phase, where we observed 63 patients from March to June 2023 in a 12-room unit, and the 'analysis' phase, focusing on 55 patients considered for admission from December 2024 to February 2024. We concentrated on admitted patients, excluding those who did not require further treatment in the ED, to focus on crucial aspects such as the arrival of specialists and the issuance of admission orders. By limiting the scope of our study to only those patients identified for inpatient admission, we maintained a consistent data collection framework, essential for ensuring the integrity and comparability of our research outcomes. We used a form that complied with the Health Insurance Portability and Accountability Act (HIPAA) standards to keep patient information private and secure. We documented every aspect of a patient's ED experience, from their initial consultation to discharge.

Working with Mr. Roarke, who was a member of the Hospital Administration Service, enabled us to utilize the Computerized Patient Record System (CPRS), which provided us with detailed patient information, particularly during the focused follow-up on admissions management. We ensured the transparency and validity of our research by clearly reporting the number of people recruited any deviations from the planned methods, and basic information about the study participants.

We performed simple analyses to identify which factors influenced waiting times and efficiency in the ED. Even though moving the ED unit temporarily for construction caused a minor delay, we continued our research in the new space. This move, along with the increase in the number of beds, presented a stimulating challenge for our study. It enabled us to observe the impact of changes in patient flow across various settings and identify effective strategies to enhance the ED's operations.

Data gathering unfolded in stages, resonating with DMAIC phases. Initially, during the Define phase in Spring 2023, we set the direction of the project. Subsequently, in the Measure phase, we documented vital metrics such as patient wait times from arrival to physician assessment and from assessment to discharge or admission, employing Data Format Template 1 (Figure 3).

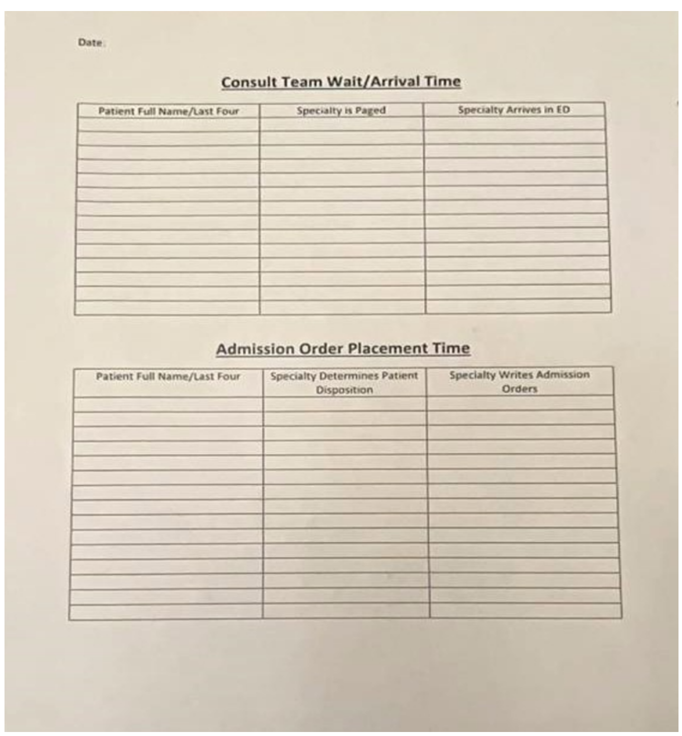
Data collected by		Time specialty provider determines pt is or isn't appropriate for admission	
Date		Will ED re-consult another specialty Y or N If Y, use second sheet and stop here	
Pt last name		Time admission orders are written by specialty provider (from CPRS)	
Pt last 4		Inpatient unit assignment	
Time ED provider determines pt is appropriate and stable for admission		Time Bed flow is notified of admission (from TEAMS Bed flow chat)	
Time ED provider places consult to Specialty Provider to evaluate patient for admission		Unit is able to accept admission at time of call Y or N	
Time EDIS button is pushed by ED Provider (should be at time of consult)		Reason transfer remains pending	
Time ED provider pages specialty service regarding consult placement		Time unit is able to accept transfer	
Time specialty provider arrives in ED to evaluate patient		Time transport from ED to unit is arranged	
Specialty Provider type		Time patient physically leaves the ED unit for inpt unit	
Additional studies need Y or N		Time patient is discharged from EDIS with time of transfer noted (get from EDIS board)	
Specific labs ordered		Additional notes on reason for possible delay in admitting patient	
Time labs ordered			
Time all Labs are completed			
Specific imaging ordered			
Time Imaging is ordered			
Time all Imaging is completed			
What other studies are ordered			
Time other studies are ordered			
Time all other studies are completed			

Figure 3. Data Format Template 1, for Patient Follow-Ups in ALM Hospital's ED

During the analysis phase, an in-depth examination of patient flow revealed delay points. Consequently, a specialized data collection template (Figure 4) was designed for targeted monitoring. This tool was intended to identify and assess bottlenecks, allowing for the development of targeted strategies to reduce wait times. This template was instrumental in recording the initial patient journey through the ED, from admission to the point of care initiation.

After progressing to the Analyze phase, a detailed examination of process flows revealed critical areas of delay—particularly concerning the arrival of specialists and the placement of admission orders. A refined data collection form, as we show in Figure 3, was developed to address these identified defects.

The template in Figure 4 was specifically designed to document the process flow and pinpoint the bottlenecks systematically. The form allows for an in-depth exploration of delays, targeting data collection at these vital junctures. The objective was to identify intervention points that could substantively reduce wait times and enhance the efficacy and efficiency of patient care.


Date:

Consult Team Wait/Arrival Time

Patient Full Name/Last Four	Specialty is Paged	Specialty Arrives in ED

Admission Order Placement Time

Patient Full Name/Last Four	Specialty Determines Patient Disposition	Specialty Writes Admission Orders

Figure 4. Data Format Template 2, for Targeted Patient Follow-up in ALM Hospital's ED

Data Analysis

Using Excel for statistical computation, we conducted a thorough data analysis. Our preparatory work involved a data cleaning and screening protocol, ensuring the reliability of the data set for detailed analysis.

We primarily focused our analytical endeavors on identifying factors that prolong the length of stay (LOS) at the Audie L. Murphy VA Hospital's Emergency Department (ED). We leveraged Lean Six Sigma methodologies within the DMAIC framework to investigate these determinants, aiming to enhance both operational efficiency and patient care quality.

We examined data from 63 patients across a year (May 23, 2022 to June 2, 2023), during the define and measure phase for calculating LOS. We analyzed the arrival time of the specialists for 53 cases, and the average arrival time was 48.4 minutes, with a standard deviation of 36.5 minutes. The time ranged from 2 minutes to 155 minutes. The distribution, as we illustrate in Figure 5, exhibits a unimodal and right-skewed pattern. We observed that most arrival times were concentrated at the lower end, with a peak around the 10–20-minute mark, This indicated that most specialties arrived quickly, although outliers extended the range. This sort of variability can provide insight into operational processes or patient urgency levels that affect specialist arrival times.

Conclusion on the Goodness of Fit

Figuring out which of the exponential, gamma, and lognormal probability distribution functions (PDFs) fits the data in Figure 5 best can help find the best model for predicting when specialists will arrive. The gamma and lognormal PDFs, being closer to the empirical data shape, appear to provide a better fit than the exponential PDF, which does not capture the tail behavior effectively. This better fit could be useful for more accurate modeling of the arrival times in operational planning and optimization.

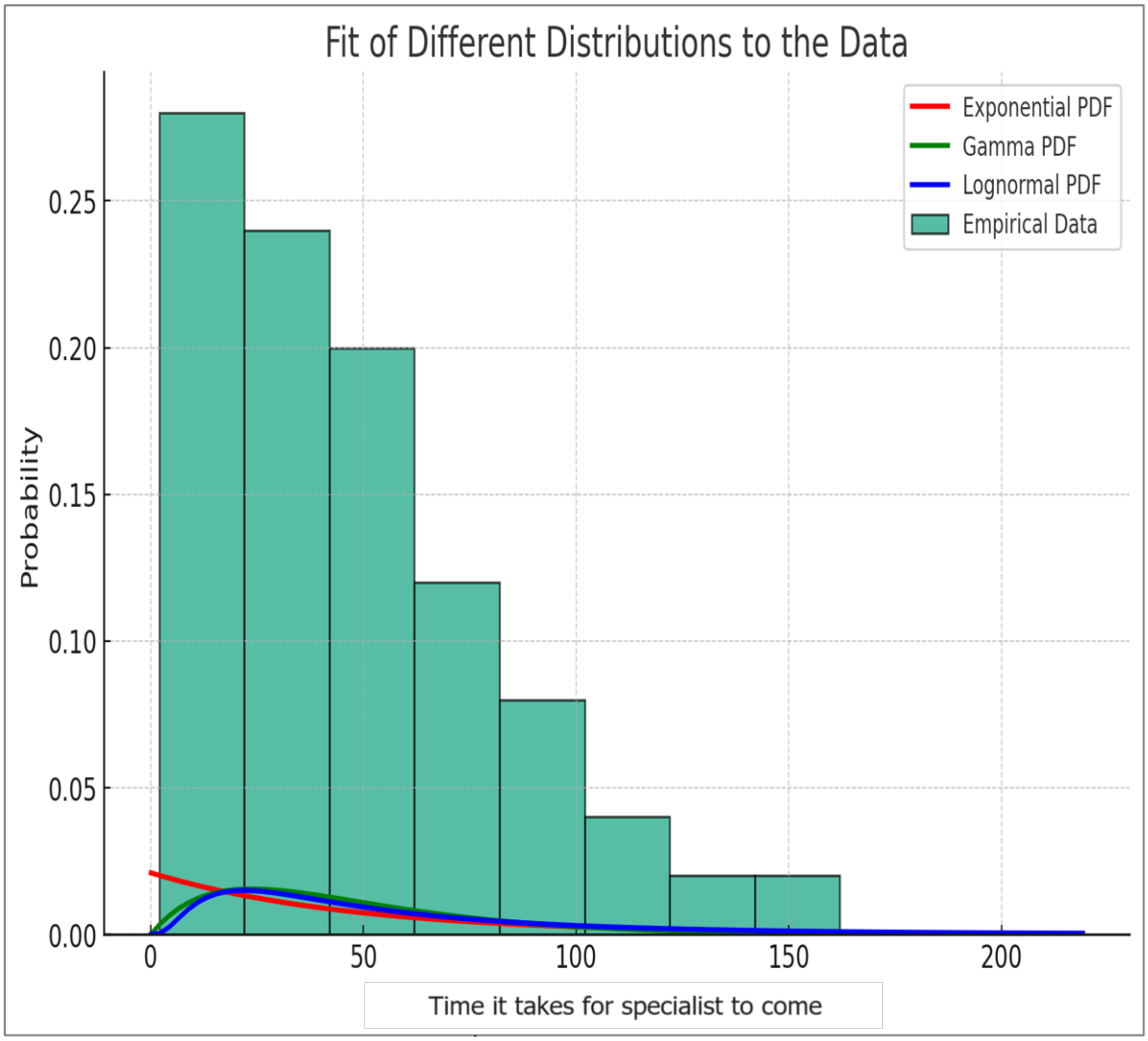


Figure 5. Fit of Different Distributions to Arrival Times of Specialists

The admission duration for 53 cases had an average time of 46.2 minutes and a standard deviation of 61.5 minutes. The data ranged from 3 minutes to 327 minutes. The distribution depicted in Figure 6 is a right-skewed pattern with a significant peak around 10–20 minutes, indicating that most admissions were processed within this time frame. The information in this figure helped convey the variability in admission times, which could reflect differences in patient processing systems or the complexity of individual cases.

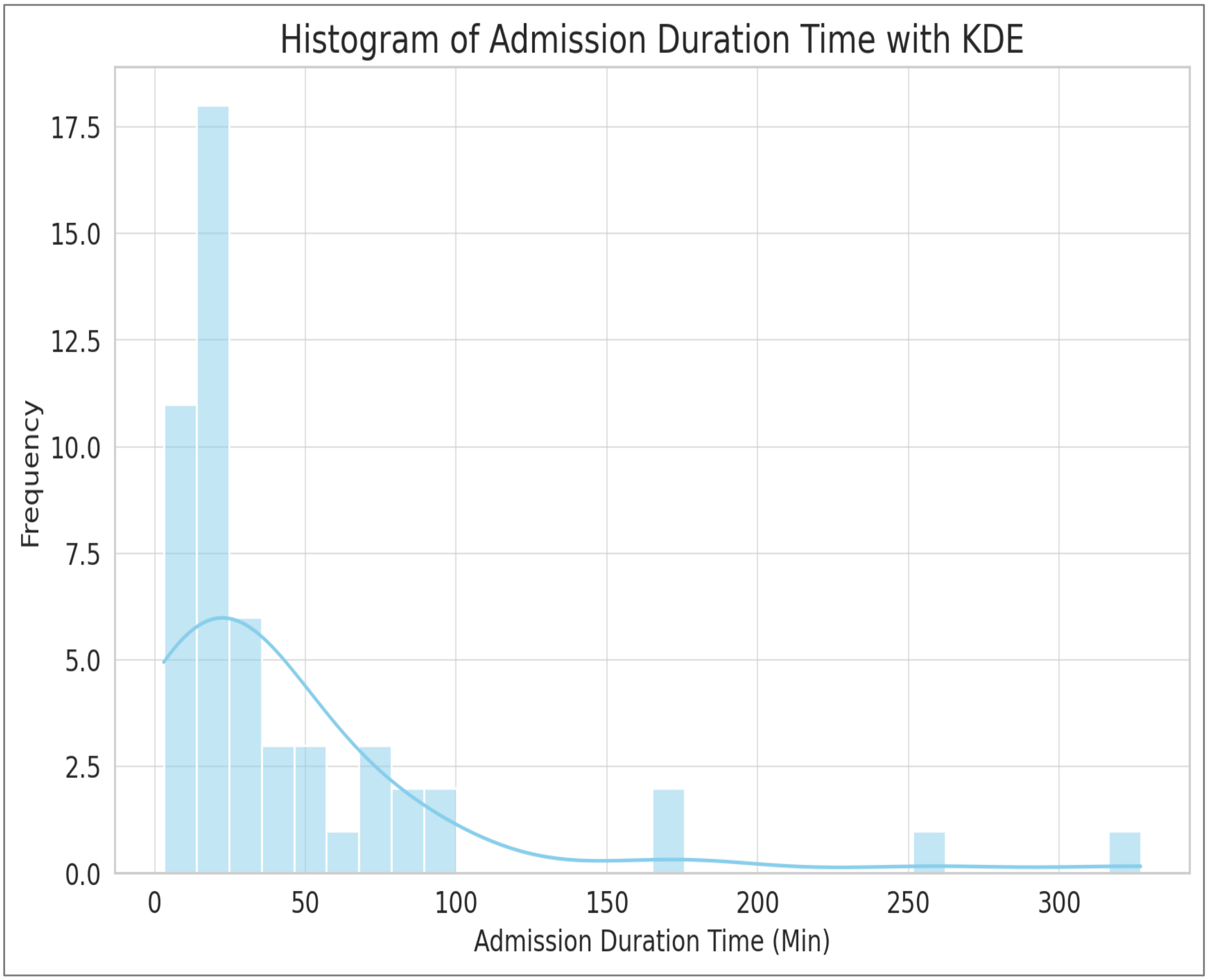


Figure 6. Histogram of Admission Duration with Kernel Density Estimate (KDE)

In Figures 5 and 6, we provide visual representations of the specialist arrival time and admission duration distributions, respectively. These illustrations were instrumental in understanding the underlying patterns and variations in the data. The analysis of these figures leads to the conclusion that while most specialist arrivals and admissions occur quickly, there are significant tails in both distributions, with some cases taking longer. This suggests potential areas for operational improvement to reduce outliers and enhance overall efficiency in patient processing.

Ethical Considerations

Throughout the Emergency Department (ED) Flow Project, we adhered to ethical guidelines to protect the privacy and confidentiality of individual patient data. We recorded each patient's data on separate individual data collection sheets, adhering to our protocol to collect data from the moment an ED provider deemed a patient suitable for admission until the patient's departure from the ED to an inpatient unit. To maintain data integrity and handle instances where a data collector could not observe the process through to the end, we implemented a handoff procedure. This involved transferring responsibility for the data to Mr. Roarke, from the Hospital Administration Service, if present, or another data collector within the ED.

In documenting the timing of the events being observed, we adhered to strict guidelines to prevent inconsistencies: this included using only VA computers to record times, prohibiting the utilization of personal devices for timekeeping, and mandating the inclusion of both hours and minutes in the documentation—maintained uniformly in military or analog format. The prohibition of personal cell phones was crucial to mitigate potential security risks within the hospital environment, ensuring that all data remained secure, and that device variability did not compromise the integrity of our time records.

In line with these detailed protocols, we ensured compliance with the Hospital's Institutional Review Board (IRB) standards. The IRB, responsible for the oversight of research ethics, particularly in studies involving human subjects, provided guidance to ensure that all compensations and interactions were ethically justified and professionally managed. We handled the data of participants discharged without admission or whose data were incomplete with equal ethical vigilance, securely destroying such information to prevent misuse. By integrating these rigorous standards into our operations, we guaranteed that our actions would be respectful of participant rights and well-being.

Limitations

The multifaceted nature of the healthcare ecosystem, with its interconnected processes and regulatory requirements, creates a complex backdrop for any intervention, potentially impeding straightforward implementation and analysis. Furthermore, the inherent aversion to operational changes among healthcare professionals may obstruct the adoption of new methodologies, such as Lean Six Sigma, within the ALM VA Hospital's Emergency Department. Comfort with established routines and skepticism of new practices often form the root of this resistance.

Another critical challenge was data accessibility; privacy regulations, fragmented information systems, and the variable completeness of medical records often hinder the acquisition of comprehensive, dependable, and timely data. These factors can severely limit the depth and breadth of analysis possible within the study.

Additionally, patient behaviors and the way they present their medical conditions to the Emergency Department are highly variable and often unpredictable. Factors such as the severity and nature of medical conditions, patient volumes, and arrival patterns introduce variability that complicates process standardization and the prediction of outcomes.

Our focus on a single emergency department raised questions regarding the transferability of its findings to other settings. The unique demographic, staffing, and operational characteristics of the studied ED may not mirror those of other departments or hospitals, affecting the broader applicability of the research conclusions. The insights gained may thus be indicative but not necessarily representative of other healthcare environments, necessitating cautious interpretation when extending the results beyond the initial context.

Summary

We have outlined our approach to studying the Emergency Department (ED) using Lean Six Sigma and the DMAIC framework. Following a thorough analysis of admission times and specialist arrivals, the project team engaged in several brainstorming sessions to discuss the findings. Due to these discussions, the project manager decided to implement a 30-day sustainment period. We made this decision to ensure the stability of our initial observations before making any further changes.

The analysis phase identified the limited number of ED beds as a key root cause, which the project team also acknowledged. The decision to wait until the department could move to a new location with increased bed capacity, which is still under maintenance, reflects this understanding.

We developed a new data collection form (Figure 3) to streamline the gathering of essential data and identify specific improvement areas within the department to aid in our ongoing analysis.

In the following chapter, we discuss the potential implications of these planned changes and increased capacity for the ED's operations. We provide an update on the progress made and outline the expected areas for improvement.

Chapter 4: Results and Interpretation

Introduction

In this chapter, we present the outcomes of the empirical investigation conducted in the Emergency Department (ED) at Audie L. Murphy Hospital (ALM) from March to June 2023. An analysis of the data, which were captured and analyzed through the Lean Six Sigma framework, offers insights into the processing times, identification of process stoppage points, and intervals for specialist's arrivals and admission orders.

Processing Times Analysis

A comprehensive review of the processing times for 63 patients provides the foundational data for our analysis. As we described in Table 1, we documented the relative frequency of these times, spanning from patient admission to departure. This quantitative analysis reveals that the plurality of patients, 27%, experienced a two to three-hour processing time, offering a key indicator for potential optimization strategies in patient flow.

Frequency Table for sample of 63		
Processing Time Range	No of patients (Frequency)	Relative frequency %
Less than 2 hours	1	1.6%
2-3 hours	17	27.0%
3-4 hours	13	20.6%
4-5 hours	12	19.0%
5-6 hours	4	6.3%
6-7 hours	12	19.0%
More than 7 hours	4	6.3%
Total	63	100.0%

Table 1. Processing Time Frequency for Patients (March-June 2023)

To visually appreciate the data in Table 1, in Figure 7 we present a bar chart displaying the distribution of processing times across various intervals. This graphical representation suggests that there was a concentration of patient processing within the two to three-hour range and the lower frequencies of more extended durations.

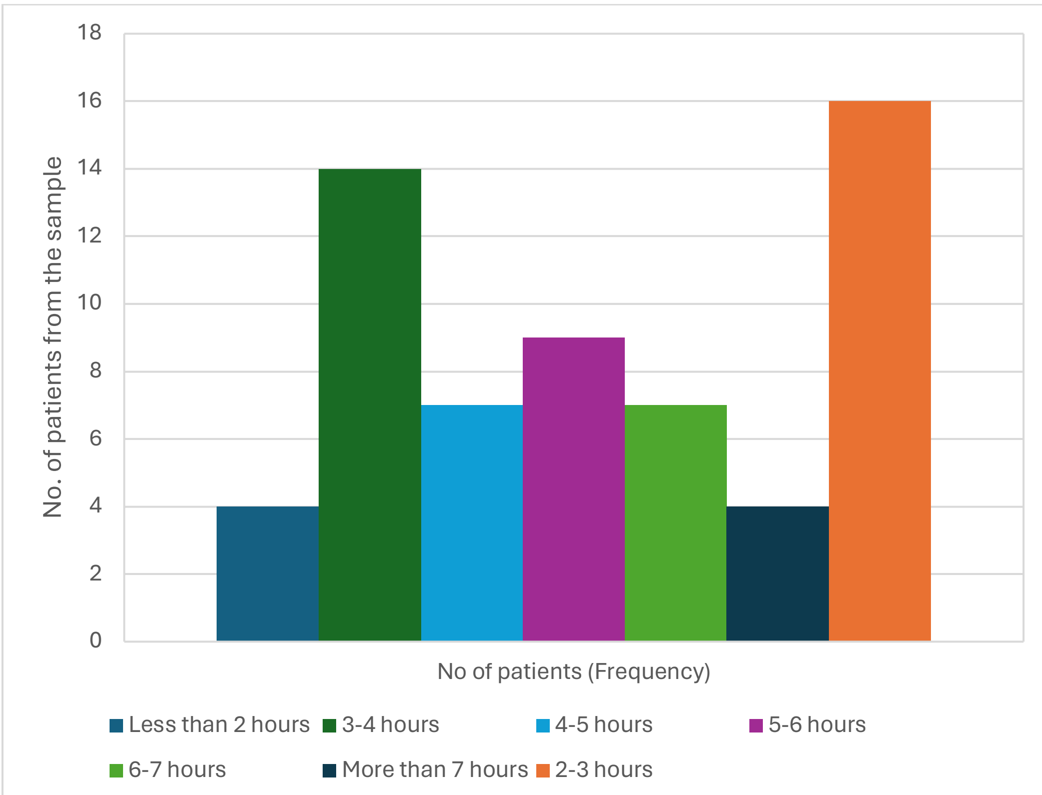


Figure 7. Distribution of ED Processing Times

Process Stoppages and Pareto Principal Application

In Figure 8, we depict the application of the Pareto principle, showcasing a prioritized list of process stoppage points by frequency and their cumulative percentage impact. We observed from the Pareto chart that specialists are the main bottleneck, followed closely by admission orders. These two critical areas collectively account for a significant proportion of the overall process delays. Specifically designed to pinpoint delay-inducing factors, the data collection form provided fresh insights into the arrival times of specialists. The results, depicted in Figure 8, indicate that most specialists arrived within the initial 15 minutes, suggesting that the interventions targeted at this step were efficacious.

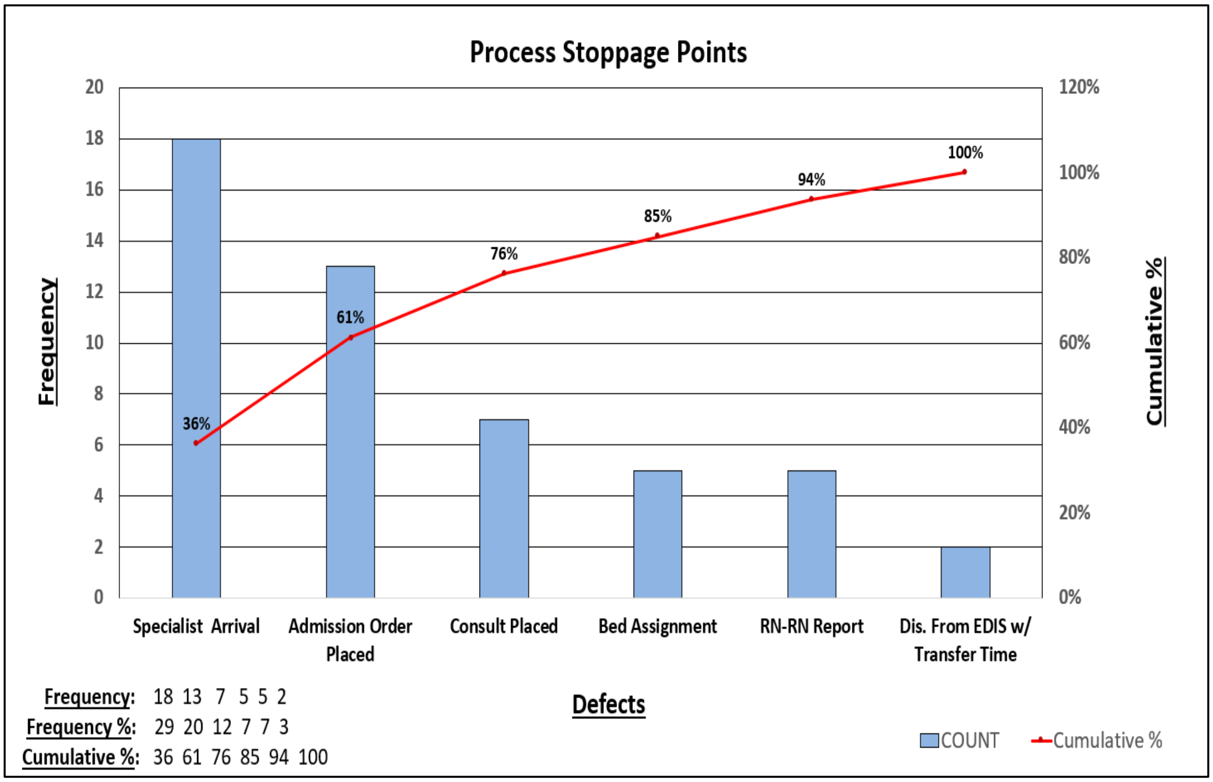


Figure 8. A Pareto Chart of ED Process Stoppages

Duration of Admission Order Placement

As we described in Figure 9, we further dissected the time intervals associated with admission order placements. we analyzed this data and found that a specific time bracket saw the highest frequency of orders, suggesting an efficient process, but also highlighting areas for further improvement.

Comparative Analysis of ED Process Improvements

We have taken a thorough look at the workflow in the Emergency Department (ED) at ALM Hospital and highlighted substantial opportunities for improving the speed and efficiency of patient care. Our approach was to closely examine the factors contributing to delays, especially focusing on the time taken for specialists to arrive and for admission orders to be processed. By comparing the periods before and after key interventions, we can distinctly appreciate the impact of the improvements.

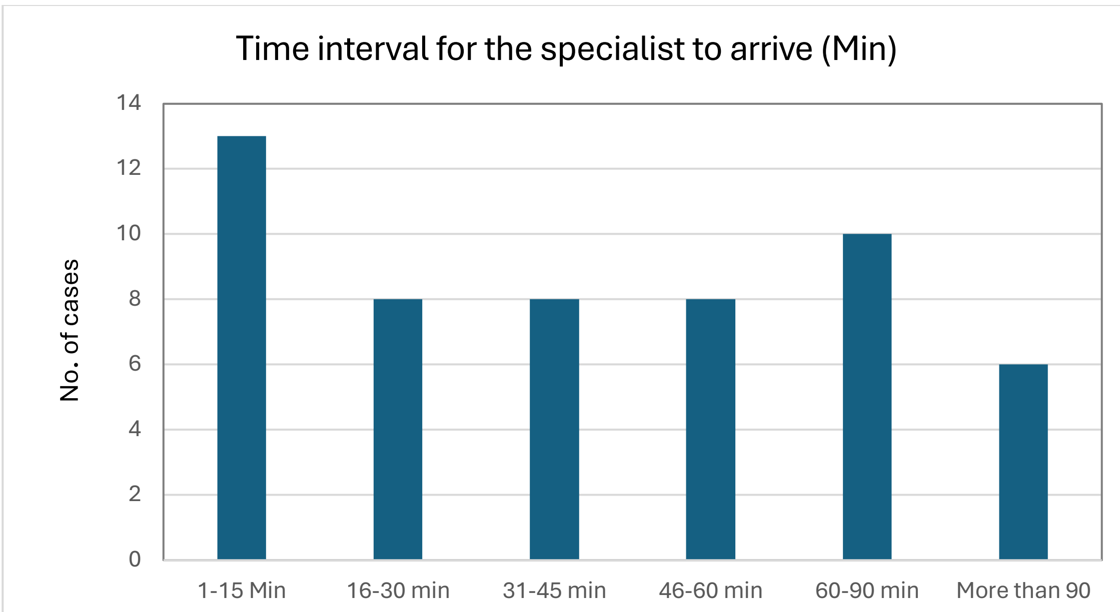


Figure 9. Time Interval Analysis for Arrival of Specialist

Before Implementation

Initially, we observed from the data that the arrival times of specialists and the completion of admission orders were areas with considerable room for improvement. As we described in Figure 10, we analyzed the distribution of admission duration times. We noted that the 3–33-minute bracket had the highest frequency of cases, indicating an efficient admission process. However, the variation in longer time brackets suggests there are opportunities for further improvement.

As we highlighted in Figure 11, prior to this quality improvement effort, the arrival of specialists was spread out through various time frames, with 33% arriving within an hour and 37% taking between 1 and 2 hours. A smaller yet significant number of arrivals exceeded 2 hours, while 14% were outliers, affecting overall patient wait times.

In terms of admission orders, in Figure 12 we show that more than half (56%) were processed within an hour. There was a sizable portion that took up to 2 hours or more, including outliers that accounted for 10% of all cases.

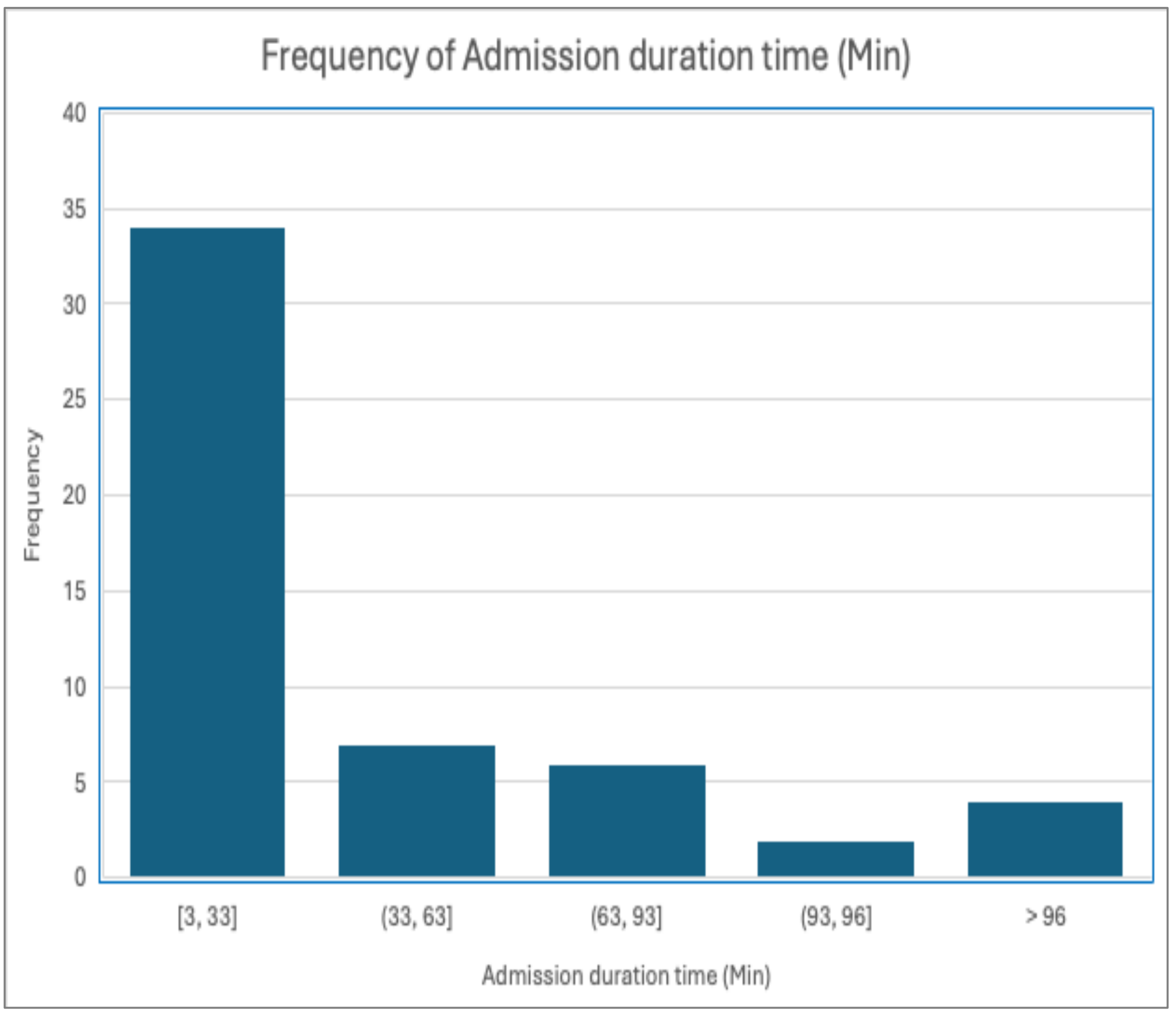


Figure 10. Analysis of Admission Order Placement Durations

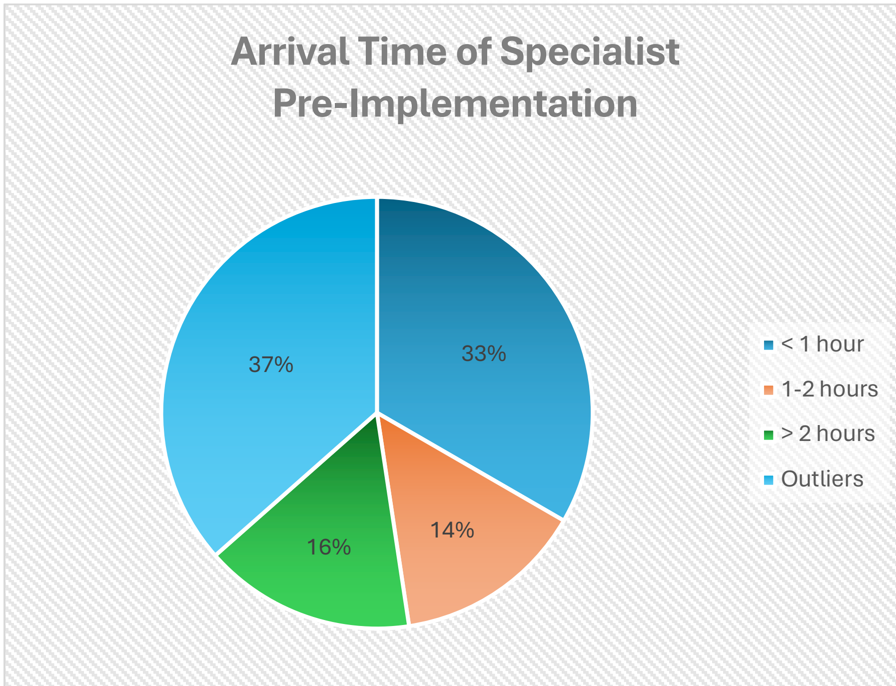


Figure 11. Pre-Implementation: Arrival Time Distribution of Specialist

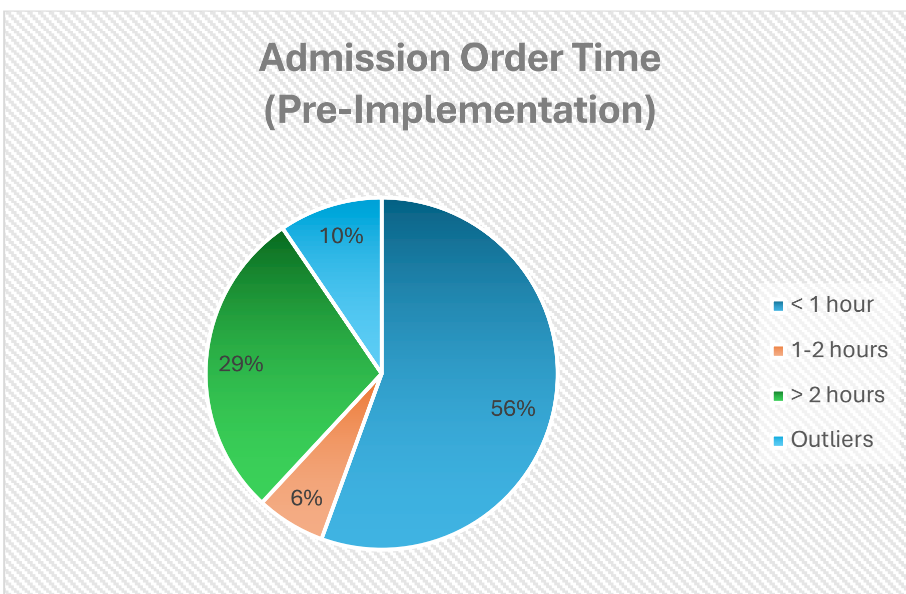


Figure 12. Pre-Implementation: Time Distribution of Admission Order

After Implementation

After the targeted meeting and the subsequent implementation of improvement strategies, we observed significant enhancements in the ED processes (Figures 13 and 14). Post-implementation, the specialist arrival times saw a marked change, with arrivals within an hour jumping to 66% and those over 2 hours dropping to 8%. This represented a substantial increase in efficiency in getting the right care for the patient promptly.

Similarly, admission order processing improved drastically, with 80% of orders being completed in less than an hour—a notable improvement from the pre-implementation figure. The changes also led to a reduction in the one to two-hour window to 13% and a drop in orders taking more than two hours to 6 percent.

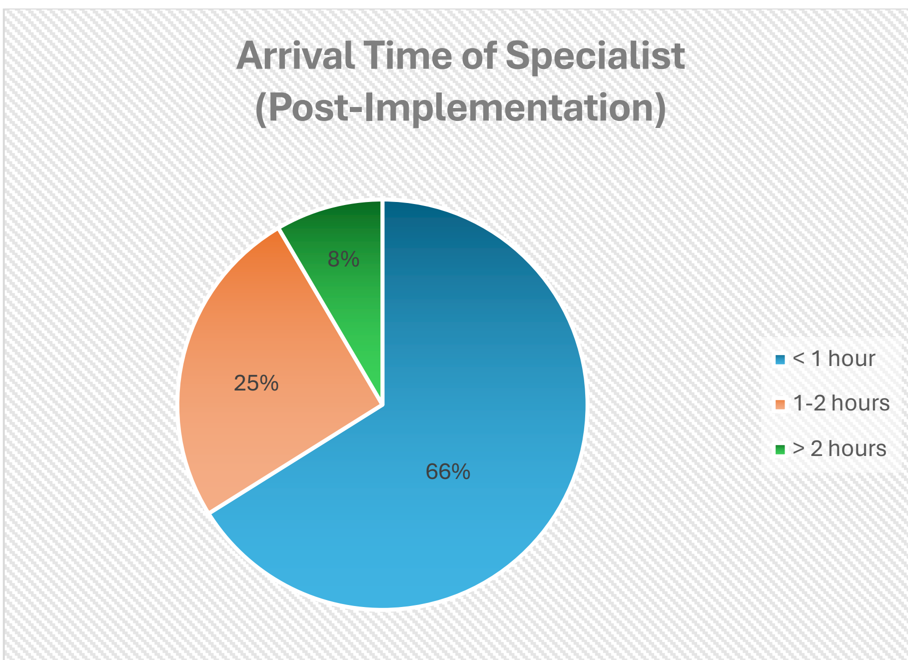


Figure 13. Post-Implementation:Arrival Times of Specialist

Summary

A comparative analysis of the pre- and post-results reveals the successful outcome of this six-sigma effort. By pinpointing and addressing the root causes of delays within the ED, we were able to implement changes that resulted in a faster and more responsive patient care process. The shift towards quicker specialists' arrivals and admission order completion post-implementation demonstrates a significant enhancement in the operational effectiveness of the ED. The clear improvement in these areas underscores the value of team collaboration, data-driven analysis, and continuous process optimization in achieving better patient outcomes.

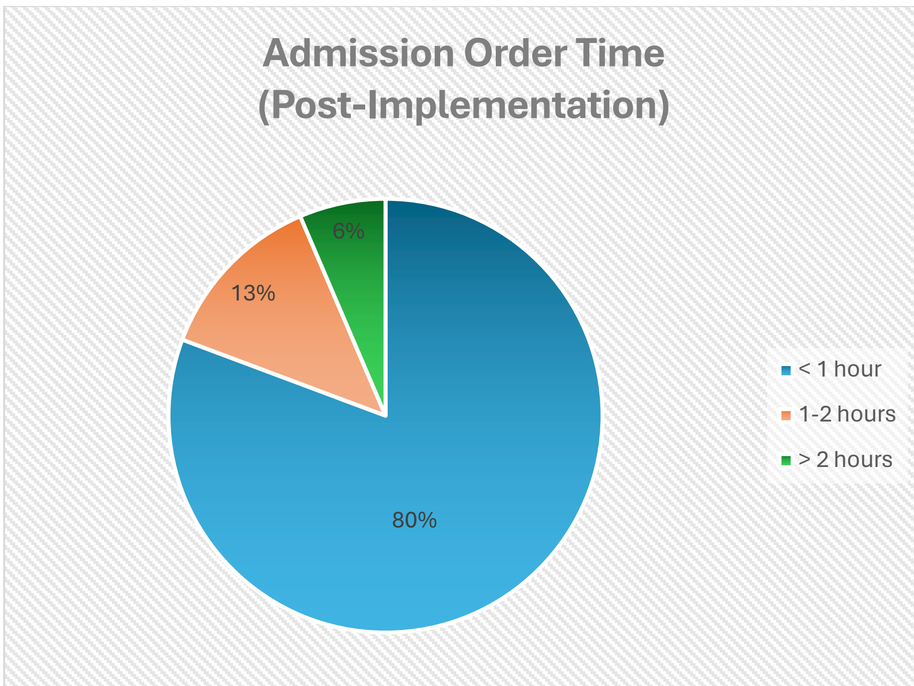


Figure 14. Post-Implementation: Time Distribution of Admission Order

Post-Implementation Review and Sustainment Planning

After the initial analysis phase concluded and the project sponsor thoroughly discussed the results, we designated a 30-day sustainment period to track the durability and stability of the implemented improvements. These sustainment checks serve as a crucial phase in ensuring that the process enhancements not only achieve immediate results but also endure over time, providing long-term benefits to the ED's operational capacity.

A cornerstone of the strategy to diminish the length of stay in the ED is the expansion of the department's physical infrastructure. We projected that the inauguration of a new ED section, which was announced during the course of this thesis, would increase the number of available beds, directly contributing to a reduction in wait times and an enhancement in the flow of patient care. We anticipated a pronounced positive impact on overall ED efficiency from this augmentation of capacity.

We expected that two new dedicated rooms for patients with COVID-19 would complement this expansion and alleviate pressure on the primary ED unit. By segmenting the care for these patients, the ED can more effectively manage resources and space, thereby reducing cross-departmental strain and improving responsiveness to the diverse needs of the patient population.

The forward-thinking initiatives reflect a commitment to continuous improvement and an acknowledgment of the dynamic demands placed upon modern emergency healthcare facilities. Although the sustainment period was not part of the scope of this thesis, it was anticipated that the Hospital's Six Sigma professionals would carry out this phase by carefully evaluating the success of these measures and closely monitoring key metrics to ensure substantial and sustainable progress.

Chapter 5: Final Remarks

Conclusions

A successful implementation of the DMAIC framework in the Emergency Department at the San Antonio VA Hospital is reported. The Define, Measure, Analyze, and Implementations phases of the framework were carried out as part of a Green Belt effort by project sponsor Roarke Verkaik-Bushby. The results, which should be maintained as part of the Control phase, showed considerable improvement.

In Appendix I, we show an email message from Ms. Stephen Bradford, Chief of Systems Engineering at the Hospital, acknowledging the benefits of this project.

The results of this study have important real-world implications. They suggest that the Lean Six Sigma and DMAIC frameworks, along with data-driven tools like fishbone diagrams and Pareto analysis, can improve operations in emergency departments. Hospitals can leverage these insights to refine patient flow processes, reduce wait times, and optimize resource allocation. Healthcare administrators can identify specific bottlenecks and use them as actionable targets, creating a blueprint for targeted process improvements that they can adapt and scale across various healthcare settings.

Limitations and Future Research

A limitation of the present work is its restricted data scope, as it was confined to the emergency room unit at the VA Hospital. Future data collection should track a patient's journey from hospital entry through the admission office, waiting room, triage, fast track room, and into the ER unit, including the timing of imaging and lab tests, to improve the accuracy of identifying issues and developing targeted interventions. This comprehensive tracking exercise would provide a more precise diagnosis of problems, enhancing the effectiveness of these interventions. We aimed to use these methods to reduce the length of stay (LOS) to meet VA benchmarks.

While the study offers valuable insights, we acknowledge its limitations due to its focus on a single hospital's emergency area. As a researcher, I faced significant barriers due to limited access to patient data, which made the research process exceedingly slow and restricted. Also, restrictions on conducting surveys and interviews with patients, their families, and staff—an essential element of Lean Six Sigma—limited our ability to obtain diverse perspectives on the issues, underlying causes, and potential solutions, which could have significantly enriched our data pool.

Future research could broaden the scope to include multiple hospitals, enabling a comparative analysis that could enhance the applicability of the results. Further research should also consider incorporating surveys and interviews to gather qualitative data that supports the quantitative findings. Expanding access to comprehensive patient data and incorporating more flexible data collection methods would expedite the research process and improve the study's thoroughness. Additionally, investigating the long-term impacts of these improvements on ED operations and patient satisfaction would provide a deeper understanding of their effectiveness and sustainability in healthcare settings.

One recommendation for future research is to collect data on patients' specific medical conditions. For example, quantifying the number of patients admitted for accidents, heart attacks, or chest pain would offer a deeper understanding of the impact the patient’s condition may have on system performance. This detailed data collection would enhance the implementation and application of Lean Six Sigma methodologies, leading to more targeted and effective improvements in patient care.

The indefatigable Lean Six-Sigma Team at the San Antonio VA Hospital will continue to apply similar principles and methods in other areas of their vast campus to further streamline patient care processes. Additionally, our approach should be considered for adoption across other hospitals within the VA system to ensure consistency and efficiency throughout the network. Furthermore, we advocate for the implementation of these strategies in private and public hospitals nationwide to enhance patient care and operational effectiveness across the broader healthcare system.

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Appendix A:
Data collection for 64 patients

Time ED provider determines pt is appropriate and stable for admission	Time ED provider places consult to Specialty Provider to evaluate patient for admission	Time EDIS button is pushed by ED Provider (should be at time of consult)	Time ED provider pages specialty service regarding consult placement	Time specialty provider arrives in ED to evaluate patient	Specialty Provider type	Time specialty provider determines pt is or isn't appropriate for admission	Time admission orders are written by specialty provider (from CPRS)	Time Bed flow is notified of admission (from TEAMS Bed flow chat)	Time admission bed is assigned (From TEAMS Bed flow chat)	Time ED RN contacts unit to give report (could be in CPRS)	Time unit is able to accept transfer	Time transport from ED to unit is arranged	Time patient physically leaves the ED unit for inpt unit	Time patient is discharged from EDIS with time of transfer noted (get from EDIS board)
12:27	MOD	12:30	12:30	13:05	Medicine	13:35	13:23	13:41	13:59	14:17	14:35	14:40	14:43	14:50
13:10	MOD	13:16	13:16	13:20	Medicine	13:30	13:33	13:38	14:47	15:00	15:00	15:02	15:22	15:35
6:40	7:03	7:04	7:00	10:00	Psychology/Medicine	10:30	13:56	14:29	15:08	15:25	15:30	15:36	15:42	15:50
10:40	MOD	11:00	11:00	11:15	Medicine	11:57	11:37	11:54/13:08	13:08	13:10	13:15	13:27	13:35	13:36
10:00	10:16	10:17	10:17	11:30	Psychology	13:00	13:14	13:21	13:35	13:45	13:45	13:50	13:50	13:59
12:45	12:53	12:55	12:55	13:30	Vascular	17:41		19:54	20:16	21:45	12:45	21:45	21:50	21:55
12:50	13:05	13:05	13:05	13:20	Pulmonary	14:51	16:53	16:56	17:23	18:16	18:16	18:16	18:20	18:26
13:30	13:41	13:45	13:45	14:45	Cardiology	15:14	15:50	16:29	16:31	17:15	17:45	17:45	17:50	18:00
11:47	11:05	11:08	11:07	11:13	Medicine	11:14	11:47	11:54	1208	13:55	14:00	14:20	14:21	14:30
11:00	MOD	11:03	11:03	11:11	Medicine	11:15	11:09	12:58	1313	13:13	13:15	13:30	13:30	13:35
12:30	MOD	12:45	12:45	13:20	Medicine	13:29	13:28	14:05	1435	14:30	14:30	14:32	15:20	15:32
11:15	11:27	11:30	11:30	12:00	Medicine Cardio	12:20	12:57	12:51	1420	13:25	14:30	14:30	14:35	14:58
8:25	MOD	12:00	12:00	14:00	Medicine	14:08	14:11	14:17	1423	14:27	14:30	14:30	15:14	15:17
11:35	11:50	11:51	11:51	13:00	Cardiology	13:16	13:14	13:14	1407	13:16	14:41	14:40	14:46	14:46
11:50	11:58	11:58	11:58	12:05	Psychology	13:00	14:44	14:49	1454	15:16	15:17	15:20	15:25	15:30
10:15	10:25	10:26	10:26/11:05	11:10	Psychology	11:33	16:12/16:55	14:24	1626	16:00	16:40	16:40	16:45	16:50
9:30		9:44	9:45	10:31	Cardiology	11:00	11:14	11:14	1202	12:35	12:40	12:35	12:50	13:01
13:00	13:06	13:08	13:08	16:00	Psychology	13:40	17:43/16:22	16:16	1622	17:30	17:30	17:30	17:40	17:45
10:04	10:13	10:14	10:14	10:36	Surgery	11:30	11:40	11:50	1206	14:21	12:30	12:50	12:57	13:00
9:30	9:35	9:40	9:40	10:57	ICU	11:30	11:57/12:33	12:18	1220	12:20	12:25	12:30	12:37	12:40
8:50	16:32	9:00	9:00	11:30	Urol/Gen surg/ MOD	12:00	14:34	14:40	1454	15:11	15:45	15:45	15:50	15:55
9:26	MOD	9:30	9:30	12:40	MOD	13:00	13:51	14:01	1420	15:00	15:20	15:20	15:30	15:35
11:30	MOD/1201	11:50	11:50	12:00	Medicine Cardio	13:50/13:41	13:08	14:09	14:33	15:10	15:15	15:15	15:20	15:25
3:50	4:03	4:05	4:05	5:15	NeuroSurgery	5:30	8:51	9:13	9:18	9:27	10:30	10:30	10:35	10:38
8:15	MOD	8:17	8:17	8:30	MOD	10:15	9:33	11:07	11:14	12:00	12:15	12:15	12:30	12:31
10:35	MOD	10:40	10:40	14:00	Medicine	14:50	12:42	13:04	13:07	14:35	14:38	14:40	14:45	15:21
5:36	MOD	7:57	7:58	8:20	Medicine	8:27	8:37	8:45	9:46	9:00	9:46	9:50	10:00	10:05
11:25	11:38	11:27	11:27	11:40	Surgery	11:42	13:46	13:14/17:25		13:50	13:55	14:00	14:05	14:05
8:30	8:47	8:48	8:49	13:50	Mental Health	14:15	14:15	14:47	14:49	14:40	14:45	15:00	15:18	15:20
10:15	MOD	10:22	10:22	10:35	Medicine	10:45	10:59		12:13	12:30	12:30	12:40	12:50	13:00
9:20	9:25	10:22	9:25	10:40	Surgery	10:50	11:03		12:13	13:54	13:55	14:00	14:05	14:07
6:32	6:42	6:42	6:42	9:30	Surgery	9:45	9:52	9:57	10:18	10:55	10:55	10:55	11:00	10:50
8:30	No Consult	8:30	8:30	10:00	Cardiology	10:15	10:36	1041	1053	11:05	11:20	11:20	11:23	11:39
11:45	MOD	11:41	11:41	11:50	Medicine	12:05	12:18	12:39	13:40	13:45	13:45	14:15	14:20	14:24
9:40	10:05	10:07	10:07	10:45	Medicine	11:06	11:17	11:52	12:02	12:10	12:15	12:18	12:18	12:27
10:00	10:17	10:20	10:18	11:00	Medicine	11:30	11:49	12:04	12:14	12:20	12:20	12:25	12:30	12:35
6:30	7:02	7:08	7:10	10:30	Cardiology	11:30	11:23	11:45	12:14	12:50	12:50	12:50	12:55	12:57
2200	2214	2215	2217	2225	Mental Health	23:12	0:25	0:27	0:41	1:19	1:30	1:27	1:38	1:42
15:10	15:30/22:51	15:32	15:30	23:45	Surgery	0:10	0:13	0:27	0:31	0:45	0:50	1:19	1:25	1:42
19:15	MOD	19:20	19:25	23:00	Medicine	23:32	23:46	23:48	0:00	0:35	0:37	0:38	0:40	1:19
21:15	21:26	21:27	21:28	23:00	Surgery	23:25	23:38	23:41	0:00	0:15	0:30	0:25	00;30	0:36
20:31	MOD	20:31	20:32	0:40	Medicine	1:00	1:19	2:06	2:09	2:42	2:45	2:50	2:59	3:00
20:50	MOD/1201	20:51	20:52	0:55	Medicine	1:20	1:36	1:42	1:59	2:45	2:45	2:50	3:01	3:02
8:00	8:15	8:15	7:55/8:05	8:30	Medicine/GU	8:45	9:03	9:51	9:59	10:25	10:30	10:35	10:40	10:50
5:20	5:38	5:40	5:40	8:50	Mental Health	9:45	10:18	11:37	11:55	12:10	12:10	12:15	12:20	12:25
1000	11:53	10:20	10:20	10:17	Medicine GI	10:30	11:03	11:12	11:55		12:45	12:45	13:02	13:09
12:14	12:29	12:30	12:31	12:45	Mental Health	13:20	14:02	14:03	14:11	14:25	15:50	15:55	16:05	16:10
4:00	MOD	4:05	4:05	6:45	Medicine	6:50	8:29	8:32	9:09	9:45	9:50	9:51	10:38	10:50
4:10	MOD	4:15	4:15	6:10	Medicine	6:15	8:27	8:32	8:48	9:10	9:12	9:14	9:15	9:36
5:44	5:52	5:53	5:53	8:12	Surgery	8:20	8:20	8:32	9:06	9:30	9:3p	9:32	9:33	9:36
9:20	9:37	9:37	9:38	9:50	Mental Health	10:45	13:13	13:20	13:36	14:00	14:05	14:05	14:10	14:16
1:40	MOD	6:17	6:17	9:00	Medicine	9:10	9:10	9:16	10:03	10:50	10:55	10:57	11:07	11:21
6:40	7:02	7:03	7:03	7:25	Cardiology	7:36	8:19	7:41	8:31	8:40	8:40	8:43	8:45	8:54

Appendix B:
Data collection details for 55 Patients, for the Improvement phase

NAME/LAST 4	ED PROVIDER	SERVICE	SPECIALIST PAG TIM	SPECIALIST ARRI L TI...	DETER MIN DISI	ADMISSION ORDE	Time it takes for the specialis come (Mir	Admission duration (Min)
Farrington 647	Van Ligten	MOD	14:36	14:38	14:40	14:55	2	15
Thomas, B. 386	Christopher	MOD	20:24	20:29	20:32	20:35	5	3
Kellum, G. 367	Johnson	urgery/Orth	17:40	17:45	17:50	23:17	5	327
Pomroy 9302	Ramos	Podiatry	15:30	15:35	17:00	17:22	5	22
Peterson 9453	Goldhagen	Psych	9:39	9:45	11:50	13:26	6	96
Olguin 2805	Ortiz	MOD	11:32	11:40	11:45	11:51	8	6
Jones, J. 0015	Jones	MOD	13:52	14:00	14:10	14:34	8	24
Williams 7112	Van Ligten	Psych	19:00	19:10	19:30	23:47	10	257
Espinosa 6498	Goldhagen	MOD	20:00	20:10	20:38	20:51	10	13
Urena 1624	Switzer	Psych	11:19	11:30	15:30	15:52	11	22
King 1524	Jones	MOD	16:47	17:00	17:08	17:15	13	7
Acosta 3920	Wood	MOD	18:00	18:15	18:36	18:57	15	21
Gutierrez 2176	Ortiz	Cards	19:00	19:15	19:25	20:06	15	41
Vasquez 0935	Van Ligten	Cards	14:03	14:20	14:35	14:44	17	9
Johnson 4690	Levada	Surgery	1:09	1:30	1:53	2:18	21	25
Pilgrim 9411	Hendiani	Cards	4:23	4:47	5:27	6:11	24	44
rnandez, O. 45	Ortiz	Cards	18:50	19:15	21:50	22:07	25	17
Black 1830	Christopher	Psych	16:01	16:30	17:01	17:29	29	28
Lara 3163	Quintana	MOD	16:21	16:50	17:18	17:51	29	33
Nevitt 5688	Hendiani	MOD	20:05	20:35	21:00	22:36	30	96
ostjohnson 37	Ortiz	Cards	11:00	11:30	11:40	12:03	30	23
Quintanilla 738	Rockoff	MOD	21:41	22:19	22:40	23:54	38	74
Franklin 0121	Andres	Cards	23:04	23:42	23:50	0:10	38	20
Grimley 1979	Koneri	MOD	3:00	3:40	4:00	4:48	40	48
Scholl 3892	Van Ligten	MOD	17:05	17:45	17:50	17:55	40	5
Callihan 7071	Switzer	Cards	18:00	18:40	21:00	21:09	40	9
Rendon 5333	Rockoff	Surgery	20:56	21:40	22:00	22:34	44	34
Ard 7784	Levada	MOD	0:30	1:15	1:45	2:08	45	23
Luhring 5169	Van Ligten	MOD	12:45	13:30	13:35	13:42	45	7
Tafolla 5999	Johnson	Cards	13:20	14:07	15:01	15:13	47	12
Cruz 3829	Switzer	Psych	17:21	18:08	18:30	19:51	47	81
Austin 2455	Hendiani	Surgery	0:36	1:27	1:43	2:08	51	25
Britten 8593	Koneri	Neuro	22:58	23:50	0:17	0:45	52	28
Housh 5712	De La Vega	Surgery	16:53	17:45	18:20	19:00	52	40
Morales 9058	Andres	MOD	00:10	1:05	1:30	1:48	55	18
Gustafson 702	Andres	Psych	3:01	4:00	6:00	6:15	59	15
Belleville 9434	Koneri	Cards	20:16	21:15	21:33	0:25	59	172
Ingalls 8944	Johnson	MOD	12:26	13:30	14:00	14:18	64	18
Valdez 2886	Hendiani	MOD	23:30	0:35	0:45	0:51	65	6
Gallegos 1979	Rockoff	MOD	1:40	2:45	3:00	3:13	65	13
Villreal 6478	Koneri	MOD	6:34	7:45	8:00	8:20	71	20
Rios 2367	Ramos	Surgery	17:48	19:00	19:20	20:30	72	70
Razodoroff 411	Hendiani	MOD	18:10	19:30	20:00	20:49	80	49
Hoyle 2480	Koneri	Neuro	0:28	1:50	2:45	3:35	82	50
Alonzo 6585	Van Ligten	MOD	17:26	18:50	19:00	20:14	84	74
Gutierrez 6847	Van Ligten	MOD	10:05	11:30	11:50	12:55	85	65
Vargas 3517	Andres	Psych	20:30	22:00	22:30	22:51	90	21
Green 4490	Jones	MOD	6:40	8:20	8:30	9:51	100	81
Farry 7613	Holt	MOD	4:20	6:00	6:45	7:02	100	17
Young 4770	Ramey	MOD	13:00	15:00	15:10	15:27	120	17
Garza, G. 749	Koneri	Surgery	21:55	0:05	0:15	3:10	130	175
Valles 1614	Rockoff	MOD	0:50	3:00	3:15	3:31	130	16
Shoemake 593	Andres	MOD	19:25	22:00	22:15	22:33	155	18

Appendix C:
Arrival Times of Specialists, Pre-Implementation

Time ED provider places consult to Specialist Provider to evaluate the patient for admission	Time specialist provider arrives in ED to evaluate patient	Time specialist provider determines pt is or isn't appropriate for admission	Time admission orders are written by specialist provider (from CPRS)
17:30	18:09	19:40	20:39
17:20	19:18	19:35	19:28
17:23	16:28	20:00	20:44
10:47	11:40	12:25	12:20
8:35	9:01	10:26	11:52
6:27	8:05	9:24	9:21
7:30	8:00	9:05	9:09
10:28	11:02	11:45	
MOD	11:40	12:50	12:53
11:36	12:21	12:27	13:20
MOD	13:05	13:35	13:23
MOD	13:20	13:30	13:33
7:03	10:00	10:30	13:56
MOD	11:15	11:57	11:37
10:16	11:30	13:00	13:14
12:53	13:30	17:41	
13:05	13:20	14:51	16:53
13:41	14:45	15:14	15:50
11:05	11:13	11:14	11:47
MOD	11:11	11:15	11:09
MOD	13:20	13:29	13:28
11:27	12:00	12:20	12:57
MOD	14:00	14:08	14:11
11:50	13:00	13:16	13:14
11:58	12:05	13:00	14:44
10:25	11:10	11:33	16:12/16:55
No Consult	10:31	11:00	11:14
13:06	16:00	13:40	17:43/16:22
10:13	10:36	11:30	11:40
9:35	10:57	11:30	11:57/12:33
16:32	11:30	12:00	14:34
MOD	12:40	13:00	13:51
MOD/1201	12:00	13:50/13:41	13:08
4:03	5:15	5:30	8:51
MOD	8:30	10:15	9:33
MOD	14:00	14:50	12:42
MOD	8:20	8:27	8:37
11:38	11:40	11:42	13:46
8:47	13:50	14:15	14:15
MOD	10:35	10:45	10:59
9:25	10:40	10:50	11:03
6:42	9:30	9:45	9:52
No Consult	10:00	10:15	10:36
MOD	11:50	12:05	12:18
10:05	10:45	11:06	11:17
10:17	11:00	11:30	11:49
7:02	10:30	11:30	11:23
22:14	22:25	23:12	0:25
15:30/22:51	23:45	0:10	0:13
MOD	23:00	23:32	23:46
21:26	23:00	23:25	23:38
MOD	0:40	1:00	1:19
MOD	0:55	1:20	1:36
8:15	8:30	8:45	9:03
5:38	8:50	9:45	10:18
11:53	10:17	10:30	11:03
12:29	12:45	13:20	14:02
MOD	6:45	6:50	8:29
MOD	6:10	6:15	8:27
5:52	8:12	8:20	8:20
9:37	9:50	10:45	13:13
MOD	9:00	9:10	9:10
7:02	7:25	7:36	8:19

Appendix D:
Arrival Times of Specialists, Post-Implementation

SPECIALIST PAGE TIME	SPECIALIST ARRIVAL TIME	Specialist Time Arrival (hr/min)	Specialist Time Arrival (min)
14:36	14:38	0:02	2
20:24	20:29	0:05	5
17:40	17:45	0:05	5
15:30	15:35	0:05	5
9:39	9:45	0:06	6
11:32	11:40	0:08	8
13:52	14:00	0:08	8
19:00	19:10	0:10	10
20:00	20:10	0:10	10
11:19	11:30	0:11	11
16:47	17:00	0:13	13
18:00	18:15	0:15	15
19:00	19:15	0:15	15
14:03	14:20	0:17	17
18:31	18:50	0:19	19
1:09	1:30	0:21	21
17:37	18:00	0:23	23
4:23	4:47	0:24	24
18:50	19:15	0:25	25
20:52	21:20	0:28	28
16:01	16:30	0:29	29
16:21	16:50	0:29	29
20:05	20:35	0:30	30
11:00	11:30	0:30	30
21:41	22:19	0:38	38
23:04	23:42	0:38	38
3:00	3:40	0:40	40
17:05	17:45	0:40	40
18:00	18:40	0:40	40
20:56	21:40	0:44	44
0:30	1:15	0:45	45
12:45	13:30	0:45	45
13:20	14:07	0:47	47
17:21	18:08	0:47	47
0:36	1:27	0:51	51
22:58	23:50	0:52	52
16:53	17:45	0:52	52
3:01	4:00	0:59	59
20:16	21:15	0:59	59
19:00	20:00	1:00	60
12:26	13:30	1:04	64
23:30	0:35	1:05	65
00:10	1:05	1:12	72
1:40	2:45	1:05	65
6:34	7:45	1:11	71
17:48	19:00	1:12	72
18:10	19:30	1:20	80
0:28	1:50	1:22	82
17:26	18:50	1:24	84
10:05	11:30	1:25	85
20:30	22:00	1:30	90
6:40	8:20	1:40	100
4:20	6:00	1:40	100
13:00	15:00	2:00	120
21:55	0:05	2:10	130
0:50	3:00	2:10	130
11:43	13:58	2:15	135
14:58	17:15	2:17	137
19:25	22:00	2:35	155

Appendix E:
Pre-implementation admission time

	A	B	C	D
1	Time specialty provider determines pt is or isn't appropriate for	Time admission orders are written by specialty provider (from CPRS)	Time admission duration time1 (hr/min)	Time admission duration time1(min)
2	19:40	20:39	0:59	0:00
3	19:35	19:28	23:53	1433
4	20:00	20:44	0:44	44
5	12:25	12:20	23:55	1435
6	10:26	11:52	1:26	86
7	9:24	9:21	23:57	1437
8	9:05	9:09	0:04	4
9	11:45			outliers
10	12:50	12:53	0:03	3
11	12:27	13:20	0:53	53
12	13:35	13:23	23:48	1428
13	13:30	13:33	0:03	3
14	10:30	13:56	3:26	206
15	11:57	11:37	23:40	1420
16	13:00	13:14	0:14	14
17	17:41			outliers
18	14:51	16:53	2:02	122
19	15:14	15:50	0:36	36
20	11:14	11:47	0:33	33
21	11:15	11:09	23:54	1434
22	13:29	13:28	23:59	1439
23	12:20	12:57	0:37	37
24	14:08	14:11	0:03	3
25	13:16	13:14	23:58	1438
26	13:00	14:44	1:44	104
27	11:33	16:12/16:55		outliers
28	11:00	11:14	0:14	14
29	13:40	17:43/16:22		outliers
30	11:30	11:40	0:10	10
31	11:30	11:57/12:33		outliers
32	12:00	14:34	2:34	154
33	13:00	13:51	0:51	51
34	13:50/13:41	13:08		outliers
35	5:30	8:51	3:21	201
36	10:15	9:33	23:18	1398
37	14:50	12:42	21:52	1312
38	8:27	8:37	0:10	10
39	11:42	13:46	2:04	124
40	14:15	14:15	0:00	0
41	10:45	10:59	0:14	14
42	10:50	11:03	0:13	13
43	9:45	9:52	0:07	7
44	10:15	10:36	0:21	21
45	12:05	12:18	0:13	13
46	11:06	11:17	0:11	11
47	11:30	11:49	0:19	19
48	11:30	11:23	23:53	1433
49	23:12	0:25	1:13	73
50	0:10	0:13	0:03	3
51	23:32	23:46	0:14	14
52	23:25	23:38	0:13	13
53	1:00	1:19	0:19	19
54	1:20	1:36	0:16	16
55	8:45	9:03	0:18	18
56	9:45	10:18	0:33	33
57	10:30	11:03	0:33	33
58	13:20	14:02	0:42	42
59	6:50	8:29	1:39	99
60	6:15	8:27	2:12	132
61	8:20	8:20	0:00	0
62	10:45	13:13	2:28	148
63	9:10	9:10	0:00	0
64	7:36	8:19	0:43	43

Appendix F:
Post-implementation admission time

1	DETERMINE DISPO	ADMISSION ORDERS	Admission Duration time 2(hr/	Admission Duration time 2(min)
2	15:01	15:13	0:12	12
3	8:30	9:51	1:21	81
4	20:00	20:49	0:49	49
5	22:15	22:33	0:18	18
6	22:00	22:34	0:34	34
7	21:00	22:36	1:36	96
8	22:40	23:54	1:14	74
9	23:50	0:10	0:20	20
10	0:45	0:51	0:06	6
11	0:17	0:45	0:28	28
12	1:30	1:48	0:18	18
13	0:15	3:10	2:55	175
14	3:00	3:13	0:13	13
15	3:15	3:31	0:16	16
16	4:00	4:48	0:48	48
17	8:00	8:20	0:20	20
18	11:45	11:51	0:06	6
19	11:50	13:26	1:36	96
20	17:01	17:29	0:28	28
21	18:36	18:57	0:21	21
22	20:32	20:35	0:03	3
23	21:50	22:07	0:17	17
24	1:43	2:08	0:25	25
25	2:45	3:35	0:50	50
26	5:27	6:11	0:44	44
27	6:45	7:02	0:17	17
28	17:50	17:55	0:05	5
29	18:20	19:00	0:40	40
30	14:40	14:55	0:15	15
31	11:40	12:03	0:23	23
32	6:00	6:15	0:15	15
33	1:53	2:18	0:25	25
34	1:45	2:08	0:23	23
35	21:33	0:25	2:52	172
36	17:50	23:17	5:27	327
37	19:25	20:06	0:41	41
38	17:18	17:51	0:33	33
39	17:00	17:22	0:22	22
40	14:35	14:44	0:09	9
41	14:00	14:18	0:18	18
42	11:50	12:55	1:05	65
43	19:30	23:47	4:17	257
44	19:20	20:30	1:10	70
45	18:30	19:51	1:21	81
46	19:00	20:14	1:14	74
47	17:08	17:15	0:07	7
48	15:30	15:52	0:22	22
49	15:10	15:27	0:17	17
50	14:10	14:34	0:24	24
51	13:35	13:42	0:07	7
52	22:30	22:51	0:21	21
53	21:00	21:09	0:09	9
54	20:38	20:51	0:13	13
55	18:25	19:13	0:48	48
56	15:30	16:14	0:44	44
57	17:27	17:32	0:05	5
58	21:28	21:58	0:30	30
59	20:12	20:33	0:21	21
60	19:09	19:29	0:20	20
61				

Appendix G:
Photos of Data Collection Process

Appendix H:
Email Message from Mr. Stephen Bradford, CLSSBB, Thesis Sponsor

Good Afternoon,
Thank you for reaching out.

I would like to share our gratitude from the Department of Veterans Affairs, South Texas Healthcare System for the work that you have helped out with on our project involving the emergency department. Your work with data collection and analyzation of that data was extremely helpful. All of the students that have assisted the VA from St. Mary's has always been extremely helpful.

V/R,

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