Applying Lean Principles to Reduce Wait Times in a VA Emergency Department

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ABSTRACT Introduction: We describe the use of Lean quality improvement methodologies at a Veterans Affairs (VA) medical facility to redesign Emergency Department (ED) front-end operations and improve ED flow, specifically to reduce time from Veteran arrival to provider evaluation. Materials and Methods: The intervention, a Rapid Process Improvement Workshop (RPIW), took place during January 2014 at the VA Palo Alto Health Care System (VAPAHCS). Key changes made as a result of the RPIW included standardizing and streamlining evaluation and hand-off processes, better-delineating roles for RNs and MDs, more efficiently utilizing beds and improving team communication. We collected 13 months of pre-intervention and 13 months of post-intervention data. The primary outcome was the change in "Door to Doctor" time between the pre-intervention and post-intervention periods at VAPAHCS compared with contemporaneous national control facility sites. Secondary outcomes included the change in "Door to Triage" time and the rate at which patients left without being seen (LWBS). Data analyses were performed using a regression-adjusted difference-in-differences approach. This was a quality improvement project and the institutional review board determined that this project does not meet the definition of human subject research. Results: Overall, "Door to Doctor" time at VAPAHCS decreased 12.6 minutes after the intervention, compared to 3.7 minutes in the control sites. Regression-adjusted difference-in-differences estimates for "Door to Doctor" time and "Door to Triage" time showed a significant reduction at VAPAHCS compared with control sites (8.9 minutes and 5.0 minutes, respectively), during the same time period (standard error = 3.5 min; $p = 0.01$ and standard error = 1.7 min; $p = 0.004$, respectively). Regression-adjusted difference-in-differences estimates for LWBS rates showed that LWBS did not significantly change at VAPAHCS compared with control sites (0.1% vs. 0.3%, $p = 0.8$). Conclusions: Using Lean principles, VAPAHCS was able to improve Veteran flow in the ED. Use of Lean methods foster interdisciplinary teams and problem-solving across departments and are one approach VA EDs can use to address systemic factors and contributors to ED crowding and improve care for Veterans. Future study should incorporate additional measures of quality to determine the effect of Lean on Veteran outcomes and should evaluate the long-term sustainability of the improvement.

INTRODUCTION

Problem Description

In a 2006 report, the Institute of Medicine's Committee on the Future of Emergency Care in the United States Health System reported on the national crisis of Emergency Department (ED) crowding.[1] Since the Institute of Medicine's landmark publication, *Hospital-Based Emergency Care: At the Breaking Point*, EDs continue to face growing problems with crowding, delays, and cost containment.[2] In particular, patient wait times and flow through the ED have come under close scrutiny.[3,4] VA EDs are not exempt from these trends, and several reports have found that ED crowding and shortages of staffing and beds, along with an absence of a diversion policy, has negatively impacted quality care provided to Veterans.[5–9]

Importance

Timely and effective care in hospital EDs are essential for good patient outcomes.[10–12] Delays before receiving care in the ED can reduce the quality of care and increase risks and discomfort for patients with serious illnesses or injuries.[10–13] The length of time patients wait to see a provider in the ED is also an important driver of patient satisfaction.[14–16] In response, many EDs are now communicating estimated wait times to the general public. The Centers for Medicare and Medicaid Services is now reporting ED wait time measures in an attempt to hold hospitals publicly accountable for the speed and efficiency of their EDs by showing comparison wait times in each community and state.

A 2005 joint report of the National Academy of Engineering and the Institute of Medicine observed that the healthcare sector has been slow to use systems engineering tools and information and communication technologies to improve the quality, safety, and efficiency of its services.[17] One promising management

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approach to achieving these aims is the Lean method. Often termed "Lean thinking," this quality improvement philosophy is a bundle of concepts, methods, and tools that grew from the Toyota Production System and is used widely in the manufacturing industry. The Lean process evaluates operations step by step to identify waste and inefficiency, and then creates new solutions to improve operations, remove waste, increase efficiency, and reduce expenses. There has been an increased interest in implementing Lean in the healthcare sector,[18] including EDs;[19] in a 2009 survey of US hospitals, of the 53% of hospitals reporting having implemented some form of Lean, 60% reported implementing Lean in the ED.[20] VHA leadership has called for the advancement of the VA healthcare system by using Lean Six Sigma, and in 2011, in an effort to improve the quality and efficiency of Veteran healthcare, the national Veterans Engineering Resource Center initiated the Lean Enterprise Transformation program to promote Lean principles and strategies in 10 VA medical facilities.

Available Knowledge

Process optimization in the ED has been well studied using a variety of quality improvement methods. Several studies have analyzed specific interventions such as adding a physician to triage or limiting inpatient boarding on ED flow.[21–26] The most commonly measured outcomes of process optimization include length of stay (LOS),[21–25,27] time to provider,[21,24,28] left without completed assessment,[21,24] and left without being seen (LWBS).[22,27] Such studies most often *a priori* select and implement an intervention that is evidence-based. Others have used multidisciplinary team-based approaches to achieve improvements.

Lean tools and methods are becoming a popular way to identify process improvements and design interventions to improve ED flow.[19,23,27–40] However, few have rigorously evaluated its use in the ED and even fewer have examined Lean in the VA setting.[40–42] Of studies to date, most have been conducted in single centers, report only pre–post measures at best, and often lack longitudinal data and use of comparison groups. When adequate comparison groups are used, the evidence is mixed at best. A recent large multi-center controlled study of Lean-based interventions in Canada found that while there were reductions in ED LOS among the 36 hospitals that participated in a Lean program, similar reductions were also observed among the 63 matched control hospitals over the same period.[29] One possible explanation for these conflicting results is the inconsistent application of the Lean principles.

Goals of Investigation

As part of a strongly supported VA Lean transformational effort, the VA Palo Alto Health Care System (VAPAHCS) ED prioritized flow redesign. The objective of our study is to (1) describe the extent and depth to which Lean methodologies are used of the use of Lean methodologies to rapidly redesign ED front-end operations that aimed at reducing waiting times to be seen by a provider and (2) evaluate if the intervention achieved its stated aim using quasi-experimental controls and a difference-in-differences approach.

METHODS

Context

The VAPAHCS ED serves a Veteran population of 85,000, spread throughout two inpatient facilities and eight outpatient clinics; the FY14 census of the VAPAHCS ED was approximately 20,000. During this study, the ED consisted of 12 acute beds, 4 Fast Track beds, and 2 treatment rooms that could be used as examination areas during overflow periods.

VAPAHCS Lean Process

ED Value Stream Scoping

The VAPAHCS ED began scoping their value stream for the ED in February 2013. The executive sponsor for the ED Value Stream was the Deputy Chief of Staff, and the two Value Stream Owners were the Chief and the Nurse Manager of the ED. The Executive Sponsor and Value Stream Owners teamed with nursing leadership and were facilitated by a Value Stream Process Improvement Facilitator, Process Improvement Coach, and Lean Consultant to form the guiding coalition for the ED Value Stream. Target states and associated metrics were defined and aligned with VAPAHCS's four strategic priority areas: people, access, quality, and safety.

ED Value Stream Analysis Event

A Value Stream Analysis event was facilitated during April 30 through May 2, 2013. Participants included the Deputy Chief of Staff, Chief of the ED, Nurse Manager of the ED, Assistant Nurse Manager of the ED, Chief of Environmental Management Service, Chief of Inpatient Mental Health, Chief of Laboratory Services, Chief of Radiology, Medical Support Assistant Supervisor, Chief of Admitting and Eligibility, a general surgeon, the Director of Quality Improvement for Inpatient Medicine, and the head of bed management. All agreed that the focus would be on Veteran flow through the ED, guided by metrics. The outputs of the event included several process improvement project charters that aligned VAPAHCS priority areas with value stream metrics and target goals. For example, for the priority area "People," the metric chosen was "Percentage of staff actively engaged in improvement work" with a goal of 85%. In the priority area "Quality," the metric chosen was "Door to Doctor time" with a goal of less than 20 minutes. Metrics and target goals were based on group consensus.

Intervention: "Door to Doctor" Rapid Process Improvement Workshop

Following the Value Stream Analysis event, a Rapid Process Improvement Workshop (RPIW), facilitated by the Value

Stream Process Improvement Facilitator, occurred January 13–17, 2014, to focus specifically on the "Door to Doctor Time" metric. The participants of this 5-day RPIW included the ED Nurse Manager, Assistant Chief of the ED, a medical support assistant, two ED physicians, and two triage/charge nurses from the ED. The RPIW began with process mapping, wherein the current process steps were diagrammed and validated. The time required for each step was estimated or measured when possible using process observation and/or electronic data. Participants also identified opportunities and ideas for improving the current state map (Fig. 1). After mapping the current state, participants solicited feedback via informal, unstructured interviews from Veterans, staff in the ED, and staff from services that support the ED. This feedback helped validate the current state map as well as highlight some possible root causes for delays in "Door to Doctor" evaluation time.

Next, bottlenecks, waste, and other process problems were identified and root causes of those problems were sought (Table I). After brainstorming and target-state mapping of possible improvements, participants proposed process redesign recommendations. Changes were adjusted in an iterative way using the plan-do-study-act cycle. The final redesign recommendations are detailed below and in Table II.

Finally, participants developed standard work documents to train staff in the new processes, communicated results of the RPIW to impacted staff, and created implementation and audit plans. These plans were also highlighted in a visual management board located in the ED. On the final day of the event, recommendations and lessons learned were presented to VAPAHCS executive leadership and management.

Final RPIW Recommendations

Four specific changes were made to systems of care and Veteran flow. First, the triage and rooming process was restructured primarily to handle high-volume periods (11:30 a.m.–8 p.m.). During peak flow hours, an additional nurse was assigned to triage duties to expedite rooming of Veterans. Utilization of nursing order protocols by the triage nurse was encouraged when appropriate. A "pull to full" strategy was employed so that when rooms were available, Veterans were brought back immediately and triaged at bedside by the primary nurse. Once roomed, all Veterans were changed into gowns, and saline lock placement was deferred until during or following a physician evaluation. The second change was made to staffing roles, detailed in Table II, which were more clearly defined to reduce confusion and rework. The third change was to standardize the huddle schedule and include all ED staff in the huddles, which greatly improved communication between staff and helped identify bottlenecks in Veteran flow. Communication was further improved by utilizing the electronic tracking system and comment field to guide huddle discussions and communicate Veteran care plans. Finally, the last significant change was the use of a proactive ED bed management system, where stable, roomed Veterans not requiring active therapy or monitoring were moved back to the ED waiting room after initial evaluation to wait for pending test results, consultations, etc. This created space within the ED to begin workups on new Veterans. Additionally, stable, ambulatory Veterans were sent to outpatient radiology and phlebotomy with a priority pass that ensured timely imaging and blood draws while freeing nurses to perform other tasks and spend more time with more critically ill Veterans.

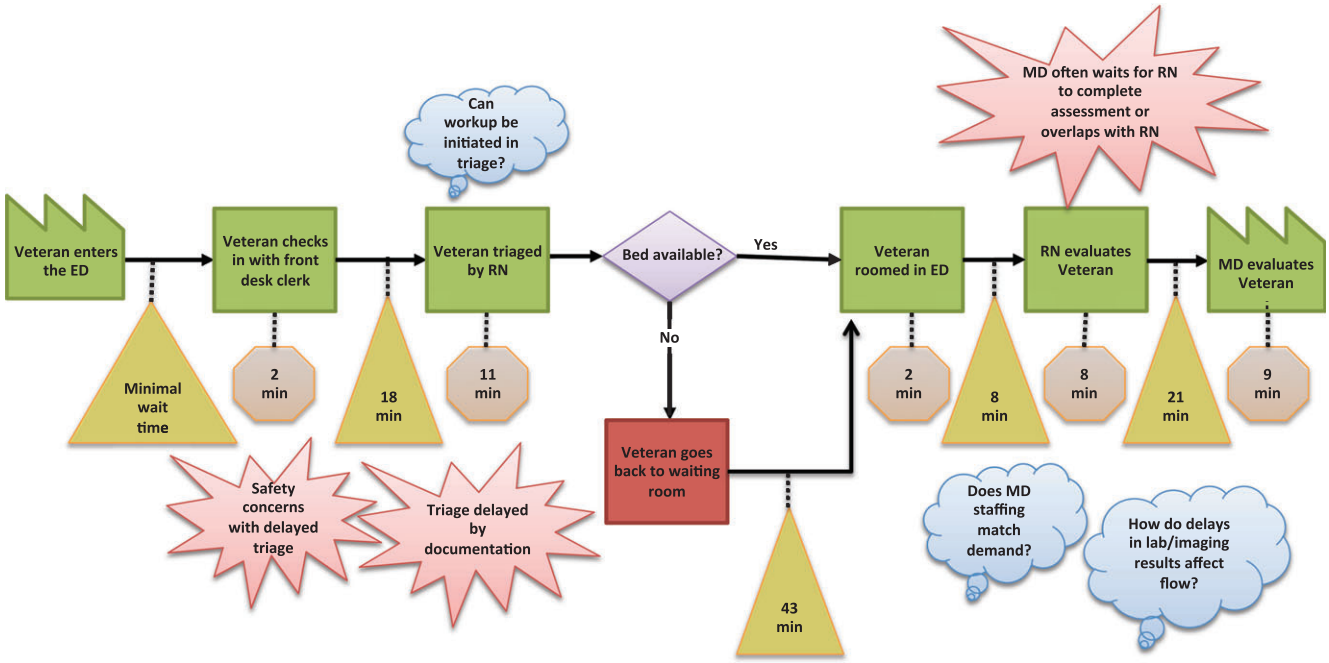

FIGURE 1. Current state map used to identify problem areas in processes.

TABLE I. Root Cause Analysis During RPIW

Identified Problems	Root Cause Analysis
Delay from Veteran check-in to nursing triage	During peak hours, volume too great for one triage nurse to handle
	No alternate processes during high-volume periods
	Non-value added documentation and travel by RNs between triages
Delay from triage to room placement	No empty beds available to room Veteran
	Admitted ED Veterans boarding and waiting for inpatient beds
	No protocol for using ED hallways or overflow exam rooms
	Some beds occupied by Veterans not requiring monitoring or treatment and only waiting for results
	Following triage, Veterans returned to waiting room even if open bed available
	Triage limited to triage intake area and often a bottleneck
	Nurse assistant frequently pulled from triage to assist in other areas
Delay from rooming to RN evaluation	RN not informed they have been assigned a new Veteran
	RN busy with other Veterans
	RN occupied with non-value added documentation
Delay from rooming to MD evaluation	Veterans are not undressed and ready for examination
	Nurse placing saline lock
	No standard for Veteran assignment. MD self-assigns
	Constant MD interruptions (ambulance, phone calls, signing EKGs)
	MD occupied with documentation

RN, registered nurse; EKG, electrocardiogram; MD, medical doctor.

TABLE II. Final Recommendations Following RPIW

Triage
Restructure triage
– "Pull to full": Veterans pulled directly into a room when available (minimize waiting room stay)
– Number of triage nurses increased from 1 to 2 during high-volume periods (11:30a-8p)
– Nursing triage protocols: triage nurse initiates workup by placing orders if ED is busy
Standard rooming and prep
– All Veterans change to gown prior to provider evaluation
– Saline lock placed after or during provider evaluation
– Primary nurse encouraged to utilize nursing order protocols when appropriate
Staffing roles
Defined nursing roles
– Charge nurse serves as Flow Manger: initiates huddles, communicates regularly with flow physician, reallocates and redirects resources as needed
– Resource nurse: responsible for overflow Veterans in waiting room, hallway and overflow helps with Veteran flow as needed
– Primary nurse: helps triage Veterans at bedside
– Fast track nurse: helps triage fast track Veterans at bedside in Fast track area
– Nursing assistant in triage: rooms and preps all Veterans, vitals, and EKGs
Defined physician roles
– Flow physician: takes all EKG reads, greets all ambulances, communicates with charge RN throughout shift
– Communication physician: fields all physician phone calls for non-specific needs (i.e., clinic transfers)
Communication
– Huddle schedule standardized (set times for day, afternoon and evenings shifts and during change of shift)
– All ED staff (nurses, physicians, medical support assistants and administrator on duty) included in huddles
– Veteran status (likely admit versus discharge) reviewed for all Veterans during huddles
– Patent flow bottlenecks identified during huddles
– Availability of inpatient and ICU beds reviewed during huddles
– Electronic tracking board used to facilitate huddles
– Comment field on electronic track board used as a communication tool for care team
Proactive ED bed management
– Stable Veterans not actively receiving monitoring or therapy (i.e., no IV, nebulizer, pain medications, safe to ambulate, etc.) moved back to ED waiting room after MD evaluation to wait for test results, social work, etc
– Ambulatory, low-acuity Veterans provided with "fast pass" to receive blood draw and imaging in outpatient center (located down the hallway from the ED)

EKG, electrocardiogram; ICU, intensive care unit; IV, intravenous; RN, registered nurse; MD, medical doctor.

Outcome Measures

The primary outcome was the change in "Door to Doctor" time between the pre-intervention and post-intervention periods in VAPAHCS versus control facility sites. "Door to Doctor" is defined as the median time in minutes between check-in and the first assignment of a provider for all ED Veterans seen during the time period specified.[1]

Secondary outcome measures include the change in "Door to Triage" time, change in LOS for admitted and discharged Veterans in the ED, and change in LWBS rate. "Door to Triage" time is defined as the median time in minutes between Veteran check-in and assessment by the triage nurse. LOS is defined as the median time elapsed in minutes between Veteran check-in and departure from the ED, and was measured for both Veterans admitted to the hospital and those discharged from the ED. LWBS occurs when a Veteran leaves the ED prior to being assigned a provider. This measure was reported as percent of total visits for the time period specified where the disposition is indicated as "left without being seen"[2] at each facility per month.

Study Design and Methods

The intervention (RPIW) at VAPAHCS took place during January 2014, and facility-level data were collected over 2 years. We considered 13 months (January/2013–January 2014) before the intervention as the pre-intervention period and the 13 months after the intervention (February 2014–February 2015) as the post-intervention period.

The data sets were extracted retrospectively from VHA Support Service Center reports. These reports provide aggregated data at the facility level with information about ED workload counts, flow performance measures, and EDIS adoption metrics. We have used aggregated facility-level data to compare the operational performance measures at VAPAHCS to other comparable VHA facilities. In order to study the changes before and after the intervention, we extracted the facility-level data from EDIS each month for 2 years with all related ED characteristics. An analytic data set was created by merging all the aggregated data sets together longitudinally.

To identify control groups, we considered all other VHA facilities with an ED that reported data during at least 1 study month ($n = 115$). Because the EDIS was undergoing a national roll-out with variable implementation just prior to the study period, only sites with good EDIS adoption were used. Adoption was defined using a nationally collected and reported measure of accuracy (0–100%) that calculates the percentage of visits where the name of the initially assigned provider matches the name of the person entering the initial provider assignment. This measure is the best available proxy for full adoption of EDIS and thus ensures higher accuracy in waiting time data; as such, it was recommended by VA EDIS implementation leaders to ensure high quality waiting time data. VAPAHCS had an average of 90% accuracy over the 2-year study period. Therefore, facility sites with low percentages of accuracy (<90%) were excluded ($n = 104$), leaving 11 control sites (Table III).

Analysis Plan

For each outcome measure of interest, daily medians (based on individual Veteran encounters) were averaged over monthly intervals for each facility. Thus, for a given outcome measure, over the 13-month pre- and 13-month post-periods, there were 26 measurement points for the intervention site ($n = 1$) and 286 measurement points for the control sites ($n = 11$).

Data analyses were performed on the primary and secondary outcomes using a regression-adjusted difference-in-differences approach. This approach measures an intervention effect while accounting for any pre-intervention differences between the intervention and comparison sites. The difference between the intervention and control groups is measured before the intervention (pre) and following the intervention (post). Therefore, in order to calculate the difference-in-differences, the difference between the intervention and control groups before the intervention (pre) is subtracted from the difference between intervention and control groups after the intervention (post). The absolute differences between the

TABLE III. ED Characteristics by Facility Site (January 2013–February 2015)

Facility	Region	EDIS Accuracy (%)	Complexity Level	Average Yearly ED Volume	# of ED Beds	Average Daily Provider Hours
Intervention Site	West	90.0	1a	18,086	16	45.7
Control A	Northeast	95.1	1c	30,321	17	32
Control B	South	95.0	1a	34,241	19	70.7
Control C	Midwest	94.1	1a	21,246	18	52.1
Control D	South	93.1	1a	25,115	28	63.7
Control E	South	93.0	1c	22,059	19	53.1
Control F	South	92.9	1a	17,764	39	103.1
Control G	Midwest	92.1	1c	22,840	10	41.7
Control H	West	92.0	1a	13,605	24	43.4
Control I	Northeast	91.7	1c	11,315	15	42.6
Control J	South	90.5	1a	16,555	16	61.3
Control K	West	90.0	1b	26,845	14	45.7

EDIS, Emergency Department Integration Software.

intervention site and the control sites are not important. It is the difference-in-differences, or the differences in the changes over time that are subjected to analysis. This means that our statistical methods remove any potentially unobserved confounding differences in the intervention and control sites that are fixed over time, apart from any that are simultaneous with the intervention.

Because a simple pre–post comparison of intervention group and control groups ignores the underlying assumptions of longitudinally structured data, a linear mixed-effect model was utilized to examine this difference in outcome measures between the pre-intervention and post-intervention periods at VAPAHCS versus control sites. This model allowed us to account for within-class correlation between sites and across time. Our analysis assessed for interaction between post-intervention period and intervention site and examined the adjusted *p*-value for this term at 95% significance level.

All statistical analyses were conducted using R statistical software, version 0.98.50 (R lme4 package was used to fit the model and R ggplot2 package was used for data visualization).

Ethical Considerations

This systematic, data-guided project was designed to bring about an immediate improvement in a local setting and was considered a quality improvement project. Additionally, the Institutional Review Board determined that this project does not meet the definition of human subject research.

RESULTS

Table III summarizes the characteristics of EDs in our study. The study included 1 intervention site (VAPAHCS) and 11 control sites. Among the control sites, there were 143 measurements in the baseline period and 143 measurements in the post-intervention period. Overall, "Door to Doctor" time at VAPAHCS decreased 12.6 minutes after the intervention, from 34.7 to 22.1, compared with 3.7 minutes from 37.2 to 33.5 in the control sites (Fig. 2). Regression-adjusted difference-in-difference estimates for "Door to Doctor" time showed a statistically significant reduction in "Door to Doctor" time at VAPAHCS compared to control sites (8.9 minutes), during the same time period (standard error = 3.5 min; $p = 0.01$) (Table IV).

In the secondary analysis, we examined the "Door to Triage" time at VAPAHCS. Overall, "Door to Triage" time at VAPAHCS decreased 6.3 minutes after the intervention from 16.4 to 10.1, compared with 1.3 minutes from 11.0 to 9.7 in the control sites (Fig. 3). Regression-adjusted difference-in-difference estimates for "Door to Triage" time showed a statistically significant reduction in "Door to Triage" time at VAPAHCS compared with control sites (5.0 minutes), during the same time period ($p = 0.004$) (Table IV). LOS for admitted and discharged Veterans at VAPAHCS decreased 42.2 minutes and 16.9 minutes, respectively, after the intervention, compared with 1.8 and 5.2 minutes at the control sites. Regression-adjusted difference-in-difference estimates for LOS for both admitted and discharged Veterans showed a

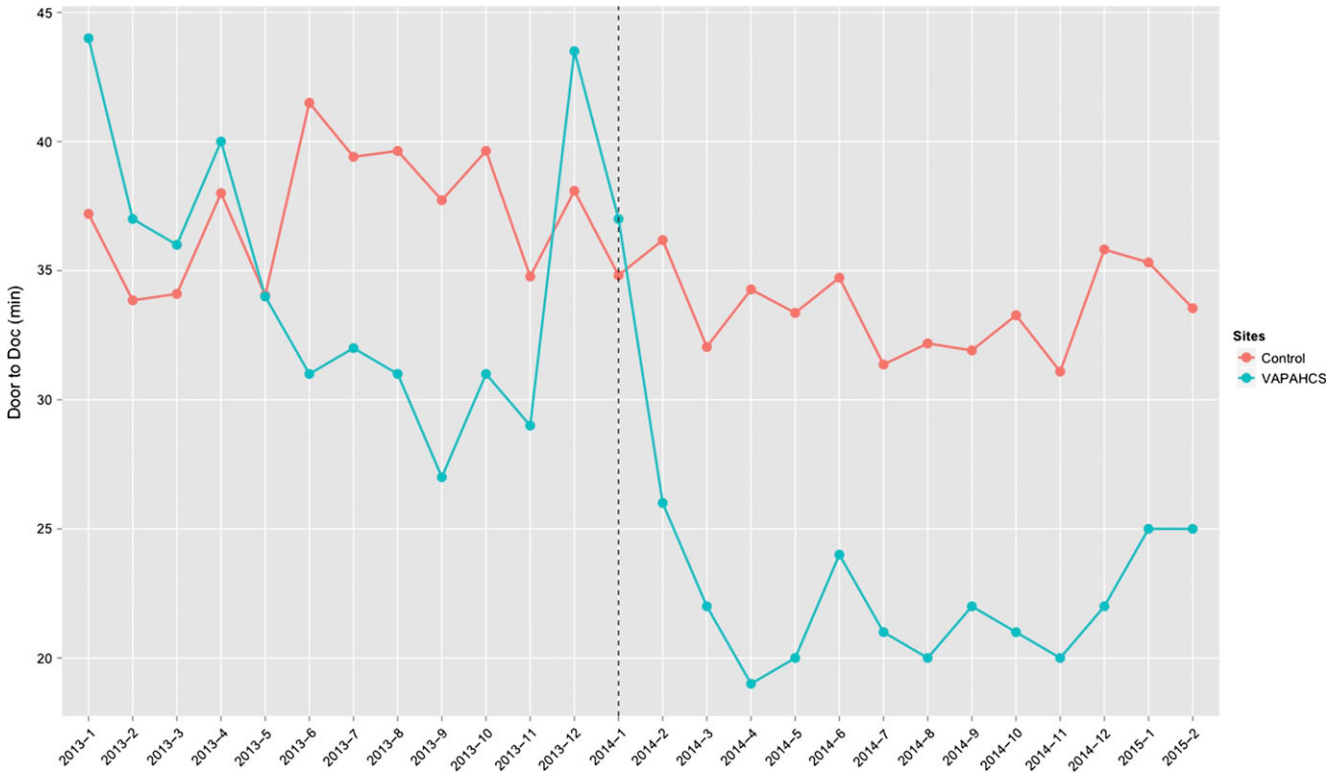

FIGURE 2. Change in "Door to Doc" over time in the intervention and control sites before and after the intervention.

statistically significant reduction in LOS at VAPAHCS compared with control sites (40.4 and 11.7 minutes, respectively), during the same time period ($p = 0.002$ and 0.04, respectively) (Table IV).

We also compared changes in the LWBS rate between the intervention and control sites. The average LWBS rate during the pre-intervention period for VAPAHCS and control sites was 0.8% and 2.0%, respectively. In the post-intervention period, rates were quite similar (0.9% for VAPAHCS and 2.3% for control sites). Regression-adjusted difference-in-difference estimates for LWBS rates showed LWBS did not significantly change at VAPAHCS compared with control sites, during the same time period ($p = 0.8$) (Table IV).

TABLE IV. Changes in Waiting Time, ED LOS, and LWBS Rate from Pre- to Post-periods

Facility Site	Pre	Post	Diff	DiD	*p*-Value of the DiD
Changes in Door to Doc time (minute)					
VAPAHCS	34.7	22.1	−12.6		
Control sites	37.2	33.5	−3.7	−8.9	0.01
Changes in Door to Triage time (minute)					
VAPAHCS	16.4	10.1	−6.3		
Control sites	11.0	9.7	−1.3	−5	0.004
Changes in ED LOS for admitted Veterans (minute)					
VAPAHCS	398.7	356.5	−42.2		
Control sites	346.9	345.1	−1.8	−40.4	0.002
Changes in ED LOS for discharged Veterans (minute)					
VAPAHCS	163.2	146.3	−16.9		
Control sites	161.8	156.6	−5.2	−11.7	0.04
Changes in LWBS rate (%)					
VAPAHCS	0.8	0.9	0.1		
Control sites	2.0	2.3	0.3	−0.2	0.8

DiD, difference-in-differences.

DISCUSSION

To improve wait times in the ED, VAPAHCS adopted Lean principles in redesigning ED front-end operations. A RPIW identified wasted steps and changes that would more efficiently allocate existing resources. These included standardizing and streamlining work processes, clearly delineating roles for RNs and MDs, efficiently utilizing beds and improving team communication. Our findings suggest that the intervention was successful in reducing "Door to Doctor" time relative to similar controls throughout the VA. Previous studies have shown that by following Lean, EDs may observe reductions in lengths of stay and waiting times however, these EDs have been limited to pre- post- data reported without use of controls, without statistical testing to test pre–post differences, and without numeric data to support reported changes.[19,43,31,30] To our knowledge, this is the first study to detail redesign efforts using Lean and evaluating changes achieved at the intervention site using control groups and rigorous methodology.

Key success factors cited for this program include the fact that, like other effective Lean interventions, flow was prioritized ahead of efficiency. Further, it was not large or resource intensive breakthroughs or modifications that led to success

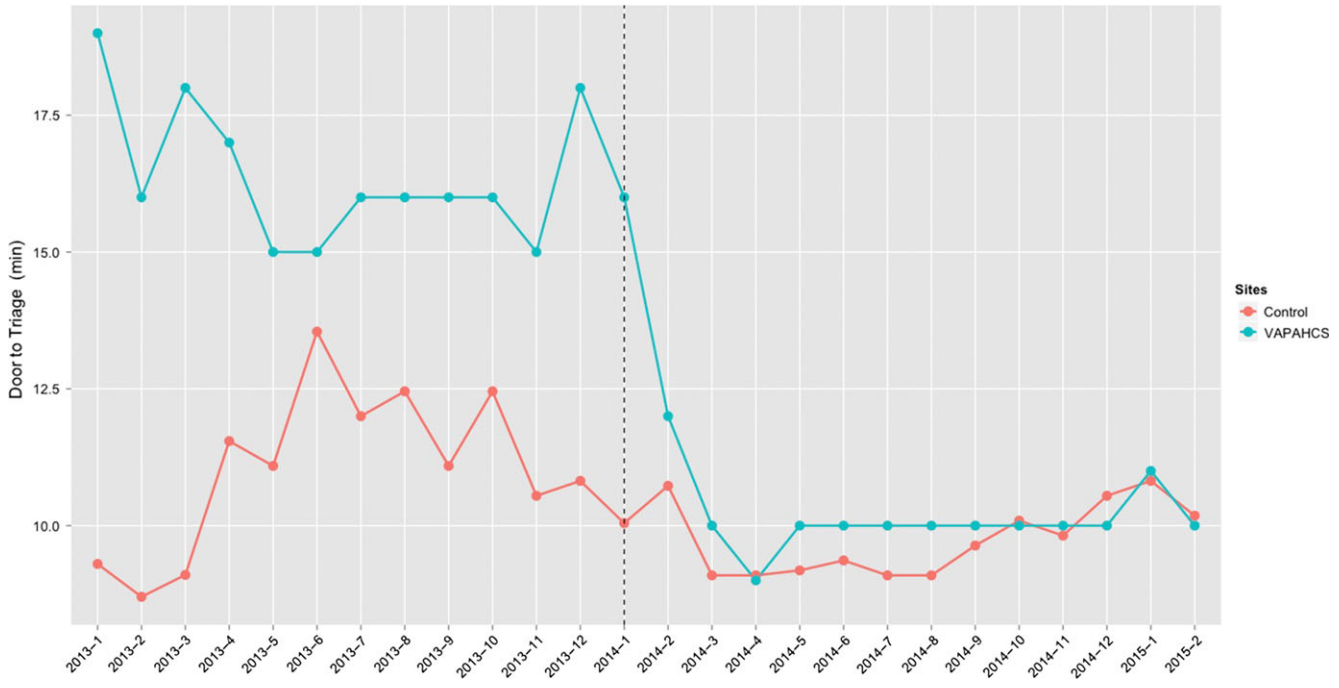

FIGURE 3. Change in "Door to Triage" over time in the intervention site and control sites before and after the intervention.

but rather multiple small process enhancements unique to local people, processes, and environment. Leadership buy-in, creating standard work surrounding the new changes, and providing visual reminders throughout the department helped ensure sustained results. Continued improvement activities like daily huddles and adoption of a Methods, Equipment, Supplies, and Staffing (MESS) board provided daily stability in the work environment. Such methods prioritized assessing and providing area readiness with emphasis on transparency of information, accountability, and follow through on quick hits and larger issues. In addition to daily huddles, other efforts such as on-going weekly VSA meetings, staff meetings, and email follow-ups promoted outstanding communication between nursing, clerical, and physician staff across various shifts. Ultimately, the improvement in flow for this value stream motivated staff to participate in future RPIWs.

Important lessons were also learned during informal interviews. Veterans reported frequently coming to the ED because they felt the ED had "great" and "timely" service, but also because they had challenges accessing care elsewhere in the healthcare system. Frontline physicians noted that lack of examination space was one of the biggest bottlenecks in examining Veterans and resulted in increasing "Door to Doctor" time. Communication with other service departments revealed ED staff could utilize outpatient lab, pharmacy and radiology services for ambulatory, low-acuity cases, freeing nurses to spend more time with sicker Veterans. This feedback was crucial to developing the final interventions.

Many factors are known to influence ED flow and LOS and have been categorized as input, throughput, and output factors.[44,45] This process improvement project focused on throughput factors, arguably the most modifiable factors from the ED's vantage point. Because these components are controlled, in large part, by the ED, ED leaders can design and implement improvements in these areas, as demonstrated here. In fact, our findings suggest that restructuring triage, among other process changes, had the most significant impact on the "Door to Triage" time, and thus the "Door to Doctor" time. However, many other factors, such as inadequate staffing levels, poor communication with laboratory and imaging services, and restricted availability or access to inpatient beds for admitted patients, are controlled by stakeholders outside the ED. In fact, one of the most common reasons cited for ED crowding is the inability to transfer admitted patients from the ED to an inpatient bed.[46,47] While the decrease in overall LOS in this study was largely driven by front-end operations, this intervention was not designed to address output factors and highlights future opportunity to further improve ED LOS. Though emergency physicians and providers often bear the brunt of the ED crowding problem, they commonly cite having little power to address its causes, since many of those causes are beyond their control. One solution to this problem is the use of Lean methods, which encourage interdisciplinary teams and problem-solving across departments. Consequently, at the conclusion of this study, the next Lean RPIW selected for the ED value stream at the intervention site was to improve efficiency from the time of ED provider evaluation to the patient's exit from the ED.

Some limitations must be considered when interpreting the results. First, data of this study may not be generalizable to other EDs, especially outside VA settings. However, ED crowding and Lean quality improvement are widespread and our findings should inform these efforts. Second, because multiple interventions were implemented simultaneously, it is challenging to determine precisely which specific component was the most impactful. However, it is important to note that there were no other significant changes to the ED system during the time period studied. For example, there were no increases in ED or hospital beds, staffing, equipment, or other resources.

Third, though ED staff and all participants were unaware of the data collection or analysis, they could not be blinded to the intervention. While the successes of the RPIW period may be partially attributed to the Hawthorne effect, we believe its overall effect has been attenuated given the lengthy follow up period.

Fourth, we attempted to minimize differences in data quality and capture between sites by selecting sites with good EDIS adoption. Doing so should bias our results toward the null. We acknowledge, however, that there may be other important differences between sites that we were not able to capture.

Additionally, we studied a limited number of metrics associated with ED flow, and other contributing factors such as inpatient census and acuity were not included. However, we did look at other unintended consequences. Finally, we chose the best proxy available to study door-to-provider time, based on when a physician assigns himself or herself to a Veteran. While this may not be the exact time a physician sees the Veteran, the same criterion was used consistently and trends in the data would contain the same amount of systematic error.

Future study should incorporate additional measures of quality to determine the effect of Lean on Veteran outcomes and should evaluate the long-term sustainability of the improvement. The next challenge is to go beyond the application of Lean tools and projects in discrete clinical areas and to develop a Lean culture of continuous learning and improvement. Such culture change is critical to a healthcare organization's success in moving from short-term performance improvements to sustained, highly reliable, evidence-based improvements that ultimately lead to transformation across the organization.

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