ED Administration

Application of Lean principles to improve early cardiac care in the emergency department

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ABSTRACT

Objective: To achieve our goal of excellent emergency cardiac care, our institution embarked on a Lean process improvement initiative. We sought to examine and quantify the outcome of this project on the care of suspected acute coronary syndrome (ACS) patients in our emergency department (ED).

Methods: Front-line ED staff participated in several rapid improvement events, using Lean principles and techniques such as waste elimination, supply chain streamlining, and standard work to increase the value of the early care provided to patients with suspected ACS. A chart review was also conducted. To evaluate our success, proportions of care milestones (first electrocardiogram [ECG], ECG interpretation, physician assessment, and acetylsalicylic acid [ASA] administration) meeting target times were chosen as outcome metrics in this before-and-after study.

Results: The proportion of cases with 12-lead ECGs completed within 10 minutes of patient triage increased by 37.4% ($p < 0.0001$). The proportion of cases with physician assessment initiated within 60 minutes increased by 12.1% ($p = 0.0251$). Times to ECG, physician assessment, and ASA administration also continued to improve significantly over time (p values < 0.0001). Post-Lean, the median time from ECG performance to physician interpretation was 3 minutes. All of these improvements were achieved using existing staff and resources.

Conclusions: The application of Lean principles can significantly improve attainment of early diagnostic and therapeutic milestones of emergency cardiac care in the ED.

RÉSUMÉ

Objectif : Pour atteindre notre objectif d'excellence en soins d'urgence cardiaque, notre établissement a mis sur pied une initiative d'amélioration du processus Lean. Nous nous sommes attachés à étudier et à quantifier les résultats de ce projet en lien avec les soins aux patients soupçonnés d'être atteints de syndrome coronarien aigu (SCA) dans notre service des urgences (SU).

Méthodes : Le personnel de première ligne du SU a participé à plusieurs événements d'amélioration rapide constitués des principes et techniques Lean : élimination du gaspillage (temps, ressources), allégement de la chaîne logistique, travail standard, et ce, pour augmenter la qualité des soins précoces fournis aux patients chez qui on soupçonne un SCA. Une revue des dossiers a également été menée. Pour évaluer notre succès, nous avons choisi, comme mesure des résultats dans cette étude « avant-après », la proportion des étapes de soins (premier électrocardiogramme [ECG], interprétation de l'ECG, évaluation par le médecin et administration d'acide acétylsalicylique [AAS]) respectant le temps visé.

Résultats : La proportion de cas où l'ECG à 12 dérivations a été fait 10 minutes ou moins après le triage du patient a augmenté de 37,4 % ($p < 0,0001$). La proportion de cas où l'évaluation par un médecin a commencé en deçà de 60 minutes a augmenté de 12,1 % ($p = 0,0251$). Le temps écoulé avant l'ECG, l'évaluation par le médecin et l'administration d'AAS ont aussi continué à s'améliorer significativement au fil du temps ($p < 0,0001$). Après l'application de Lean, la durée médiane entre l'ECG et l'interprétation par le médecin était de 3 minutes. Toutes ces améliorations ont été obtenues en ayant recours au personnel et aux ressources existantes.

Conclusions : L'application des principes Lean peut améliorer significativement l'obtention d'un diagnostic précoce et la rapidité des étapes thérapeutiques de soins d'urgence cardiaque au SU.

Keywords: acute coronary syndrome, Lean principles, process improvement, time to acetylsalicylic acid administration, time to electrocardiogram, time to physician assessment

A substantial body of medical literature exists on the topic of the emergency treatment of acute coronary

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syndrome (ACS) and emphasizes the importance of minimizing the time to diagnosis, early therapy, and reperfusion. Despite this, many North American hospitals fail to meet well-established ACS standards of care and, as they currently function, may be ill-equipped to do so.[1–6] In the current era of hallway medicine and overcrowding, many Canadian emergency departments (EDs) struggle to provide excellent care to patients who present with suspected ACS. Without timeliness, excellent acute cardiac care is not possible. The current tertiary ED approach to chest pain may miss 5.3% of ACS cases, and delayed diagnosis remains a leading cause of medicolegal actions in Canada.[7] Clearly, new tools and approaches are required.

"Lean" is a process improvement strategy, initially developed in the Japanese manufacturing sector, that focuses on streamlining complex processes by eliminating or improving "non–value-added" steps. Recently, American, Australian, and Canadian EDs have effectively applied Lean principles.[8–12] Their successes demonstrate the applicability of Lean to the health care sector.[13] However, little research has been conducted in this area, particularly regarding ACS care specifically.

Our tertiary care ED has over 40,000 visits yearly. In 2006, our hospital was designated a "Cardiac Centre of Excellence," with consolidation of cardiac surgery, cardiology, and percutaneous coronary intervention services at our site. As a result, a steadily increasing proportion of the region's chest pain patients present to our ED. In April 2008, "chest complaint, non-trauma" was the fourth most common presenting complaint in our ED. Between May 2007 and June 2008, the number of ED patients admitted to cardiac care services doubled, and the timeliness of early diagnostic decision making such as electrocardiography (ECG) and basic interventions became an issue. Most concerning were intermittent reports of missed or severely delayed ACS diagnosis in patients seen in the waiting room. This situation, although difficult to face and demoralizing for ED physicians and staff, became our impetus for action.

In 2007, our institution adopted Lean as a primary quality improvement strategy. The purpose of this study was to evaluate specific clinical outcomes related to cardiac care in our ED before and after the first 10 months of Lean implementation.

BACKGROUND ON LEAN THINKING

Lean is an approach to process improvement that focuses on 1) improving complex processes by eliminating waste to increase value in the eyes of the customer and 2) empowering front-line staff to identify waste and create solutions for immediate implementation.[14] In the manufacturing sector, Lean originated from the Toyota Production System. The health sector's "customer" is the patient, and as with industry, an efficient flow of complex processes, people, and supplies is necessary to deliver safe, high-quality care.[15]

After choosing a process requiring improvement, the business of Lean is typically accomplished during weeklong *kaizens*, or rapid improvement events (RIEs). Here, teams of front-line staff conduct a value stream analysis (VSA) by creating a detailed visual map of the steps in the process under review as it actually functions.[16] Each step, or operation, is analyzed to identify various kinds of waste. Teams are challenged to identify root causes of inefficiencies, and potential solutions that maximize the value-added portions of the process are tested immediately.

In addition to VSA, Lean, as it applies to health care, emphasizes consistent patient flow, tight connections between care providers (e.g., emergency, diagnostic imaging, and laboratory staff and consultants), elimination of batching and/or queuing, and standardization of supply chains, information handling, and workspaces.[17,18] These techniques would be anticipated to decrease the clutter, errors, delays, and frustrations that plague many contemporary EDs.[19] To be effective, Lean requires a significant cultural shift in most hospitals and thus requires high-level administrative support.

METHODS

Intervention at the study site

Practical implementation of Lean thinking at our hospital began in 2008. Executive-level workshops introduced Lean to key leaders and set future goals for the entire institution. This unequivocal endorsement from senior management permitted staff to commit fully to the process, and many paid employee hours were devoted to Lean activities. Care of suspected ACS patients (from triage to departure from the ED) was identified as a key area for improvement. In July and

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August 2008, external Lean consultants led VSA workshops. Participants documented current ED care processes for patients with suspected ACS ("initial state"), designed a simplified, idealized care flow ("target state"), and identified gaps and/or challenges separating the current operational state from the ideal. The workshop teams were composed of diverse groups of front-line staff, including emergency administrators, nurses, physicians, residents, and porters.

During these sessions, value stream mapping indicated that times to first 12-lead ECG and administration of acetylsalicylic acid (ASA) were often suboptimal, despite the existence of an ACS care map that provided clear guidelines regarding initiation of these evidence-based care milestones. Once ECGs were performed, emergency physicians were frequently busy and unable or unwilling to interpret them until patients were moved to a bed. Several inefficiencies emphasized by Lean, including batching or queuing of patients, nonstandardized work areas, paperwork duplications, unnecessary movement, and excessive demands on triage nurses' attention and time, were identified as root causes of delays.

These issues were addressed during the following RIEs held at our hospital, which focused on the initial assessment and treatment of suspected ACS patients:

- "ACS Patient Flow from Presentation to ECG Interpreted" (September 8–12, 2008)
- "Lead Time from Triage to Treatment for ACS Patients" (October 6–10, 2008)
- "Sustainment: Triage to First MD Assessment" (February 2–6, 2009)

RIE teams designed all process improvements in response to problems they identified. These changes were implemented immediately and are now part of our ED's new operating procedure. Examples include the following:

- Relocating the "home base" of the ECG technician or machine from the third floor to the ED
- Creating a dedicated ECG room, equipped with two stretchers, next to triage
- Establishing the triage nurse (rather than the registration clerk) as the first patient contact
- Relocating triage chairs, electrical outlets, and intravenous pumps to decrease unnecessary patient and triage nurse movement
- Defining a procedure for immediate physician interpretation of ECGs
- Refining risk stratification tools for triage nurse use and clarifying criteria for activation of the ACS care map
- Creating a "pull" system for potential ACS patients by having physicians identify available spaces and flag patients able to move to less acute areas

Several weeks after the first two RIEs, ED staff noted a lapse in maintenance of new initiatives. A "sustainment" RIE was conceived in response to the belief that we could do better and focused on re-examining front-end processes and recreating an environment of continuous improvement. Key achievements included empowering orderlies and nurses' aides to deliver all ECGs directly from triage to the physician for immediate interpretation and solidifying physician support for this new procedure.

Performance data were summarized and reanalyzed on a monthly basis. Each update formed the basis for further changes to the process of identifying and streaming suspected ACS patients. New results were displayed in the ED to promote staff engagement and participation, both essential elements of Lean.

Outcome measures

We compared pre- and post-Lean proportions meeting prespecified targets of the following care milestones: 1) first 12-lead ECG, 2) ASA administration, and 3) patient assessment by a physician. The details of these primary outcome measures are provided in Table 1. The time from performance of the first 12-lead ECG to interpretation by a physician, a key decision point, was not tracked prior to Lean. Target times and proposed benchmarks were chosen in response to institution-specific goals and existing literature-defined standards, specifically the American College of Cardiology/American Heart Association (ACC/AHA) ACS management guidelines and Canadian Cardiovascular Outcomes Research Team/Canadian Cardiology Society (CCORT/CCS) quality indicators for the care of acute myocardial infarction.[20,21] These easily measurable and widely supported end points are congruent with Lean thinking, which promotes consistency and setting optimal process improvement goals, regardless of whether they are initially achievable.

Implementation of Lean techniques for suspected ACS patients began in mid-September 2008. Data up to and including November 2008 were not examined

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Table 1. Primary outcome measures of study

Outcome measure	Target time	Abbreviation	Benchmark goal
Proportion of first 12-lead ECGs completed	≤ 10 min from triage	ECG	90% of the time
Proportion of first 12-lead ECGs interpreted by a physician	≤ 5 min from ECG completion	ECG-I	100% of the time
Proportion of patients assessed by a physician	≤ 60 min from triage	MD-A	90% of the time
Proportion of patients receiving appropriate ASA	At home, by EMS, or ≤ 3 h from triage	ASA	90% of the time

ASA = acetylsalicylic acid; ECG = electrocardiogram; EMS = emergency medical services.

owing to the steep learning curve required of staff and frequent adjustments to documentation and data-gathering methods. Outcome data from a 10-month post-Lean period (December 2008 to September 2009), with all patient identifiers removed, were abstracted from Lean data collection sheets placed on suspected ACS patient charts by the triage nurse and filled out in real time by care providers. Inclusion criteria and our working definition of "suspected ACS" are provided in Table 2 and were adopted directly from our hospital's pre-existing ACS care map. The only exclusion criterion was traumatic chest pain. Data collection sheets were collected and compiled into a secure computerized database by hospital administrative staff designated as Lean leaders for the ED ACS project, who were not involved in data analysis for this study.

A medical records review was conducted to obtain historical data. To select a control population comparable to post-Lean suspected ACS patients, the following search criteria were applied to a historical emergency program computerized database kept in our health region: ED visit date December 1, 2007 to September 30, 2008 (1 year prior to study population visits) and triage complaint of "chest pain" or "chest complaint: non-trauma." This produced a potential historical control group of $n = 3{,}808$. A power calculation (*SAS* version 9.2, SAS Institute, Cary, NC) indicated that 170 subjects were required to detect a 15% absolute increase in ECG time < 10 minutes. Using *SAS*, a list of random integers was generated and used to select visits from the chronological list of 3808 eligible control visits. The principal investigator reviewed 250 charts and excluded those lacking a 12-lead ECG (final control population $n = 229$). Triage time, ECG time, physician assessment time, and ASA administration, if documented, were abstracted using standardized forms. A second physician abstractor, blinded to initial abstracted data, reviewed 10% of control group charts, with concordance of 86% achieved.

Table 2. Inclusion and exclusion criteria for suspected ACS patients

Patients with the following signs and symptoms require immediate assessment by the triage nurse for the initiation of the ACS protocol:

Chief complaint:

Chest pain or severe epigastric pain, nontraumatic in origin, with components of myocardial ischemia or AMI:

- Central/substernal compression or crushing chest pain
- Pressure, tightness, heaviness, cramping, burning, aching sensation
- Unexplained indigestion, belching, epigastric pain
- Radiating pain in neck, jaw, shoulders, back, or one or both arms
- Associated dyspnea
- Associated nausea/vomiting
- Associated diaphoresis

Medical history:

The triage nurse should take a brief, targeted, initial history with an assessment of current or past history of the following:

- CABG, angioplasty, CAD, angina on effort, or AMI
- Nitroglycerin use to relieve chest discomfort and response
- Risk factors, including smoking, hyperlipidemia, hypertension, diabetes mellitus, family history, and cocaine use

Atypical presentation:

- Women may present more frequently than men with atypical chest pain and symptoms
- Diabetics and dialysis patients may have atypical presentation or present without pain owing to autonomic dysfunction
- Elderly patients have atypical symptoms such as generalized weakness, stroke, syncope, or a change in mental status
- Recurrent visits with atypical symptoms

ACS = acute coronary syndrome; AMI = acute myocardial infarction; CABG = coronary artery bypass graft; CAD = coronary artery disease.

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Chart and database reviews were conducted with the approval of our institutional Research Ethics Board.

Statistical analysis

Time to first 12-lead ECG (ECG time) was calculated using the triage time (captured by a pre-existing computerized triage program) and the time printed on the ECG tracing. Delay to physician interpretation of first 12-lead ECG (ECG-I time) was subsequently determined using the time written on the ECG by the physician during interpretation. Time to first physician assessment of suspected ACS patients (MD-A time) was calculated using the computerized triage time and the assessment time noted by the resident or attending physician on the Lean data collection sheet.

SAS version 9.2 was used for statistical analysis. A simple chi-square statistic was used to compare outcome measures pre- and post-Lean. We also conducted a month-by-month analysis of the data, using the Cochran-Armitage test for trend, to evaluate how sustained any improvements in our outcomes of interest were over time.

RESULTS

Data sheets were initiated in approximately 40% of eligible presentations during all shifts, resulting in a convenience sample of $n = 1{,}437$. Post-Lean, 58.2% of physician assessment times were captured.

Figure 1 provides results for the primary outcome measures pre- and post-Lean. Pre-Lean, only 5.2% (12 of 229) of 12-lead ECGs were completed within the target time. Post-Lean, this proportion increased to 42.6% (612 of 1,437), an absolute increase of 37.4% ($p < 0.0001$). The proportion of physician assessments completed in ≤ 60 minutes improved by 12.1% (35.1% to 47.3%, $p = 0.0251$). No change in the rapidity of ASA administration found.

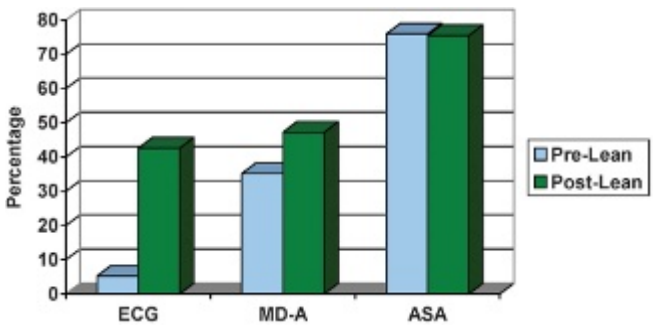

Figure 1. Results of primary study outcomes pre- and post-Lean. ASA = acetylsalicylic acid administration (target at home, by emergency medical services, or ≤ 3 hours after emergency department arrival); ECG = electrocardiogram time (target ≤ 10 minutes); MD-A = time to physician assessment (target ≤ 60 minutes).

A month-by-month analysis found a significant and continued improvement over time, with increasing proportions of ECG times ≤ 10 minutes, MD-A times ≤ 60 minutes, and ASA administration < 3 hours (all p values < 0.0001). The results for this analysis for the ECG outcome are shown in Figure 2. Median ECG and MD-A times at the end of the study period are shown in Figure 3 and Figure 4 and were markedly improved when compared to pre-Lean values.

Post-Lean, the average delay from ECG performance to physician interpretation (ECG-I) was only 5 minutes (median 3 minutes); 78.8% (965 of 1,224) of recorded ECG-I times met our goal of ≤ 5 minutes. After incorporating the documentation of ECG-I time into the standard work of emergency physicians, we succeeded in recording 85.2% (1,224 of 1,437) of all ECG-I times.

DISCUSSION

Lean thinking examines the sequence of operations that comprise each process and groups similar processes together in value streams to increase efficiency.[16,17] The ED care of suspected ACS patients is an example of a complex task that lends itself well to Lean application. Rather than prescribing a generic set of solutions, "quick fixes," or technology-based interventions, Lean provides an approach to understanding and analyzing processes. In the health care environment, this allows workshop teams to tailor improvements to the unique realities of their hospital or department. Lean de-emphasizes cost cutting and evaluation of individual staff performance, leaving those parameters to be indirectly improved by eliminating systemic inefficiencies and inspiring staff to deliver high-value service.

The unmitigated successes found in our study speak to both the power and relevance of Lean as a process improvement tool and the dedication of our staff. Resistance to change, particularly among physicians, was a significant obstacle. Their genuine support of changes in daily practice habits was essential to consistently increase the value of service delivered, the fundamental aim of Lean.

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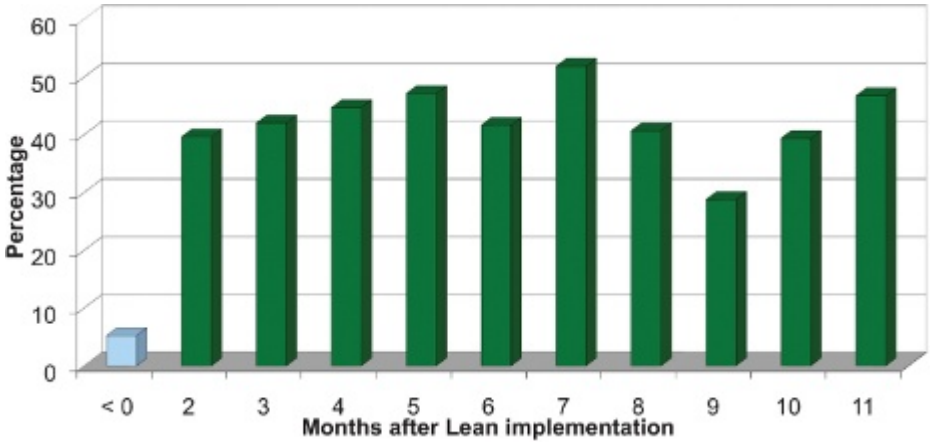

Figure 2. Proportion of first 12-lead electrocardiograms completed ≤ 10 minutes after triage. Bar at far left (< 0) indicates pre-Lean value; values for each post-Lean month (December 2008–September 2009) follow.

Over 10 months after Lean implementation in the ED, our ED has continued to improve adherence to early cardiac care milestones, specifically first 12-lead ECG, ECG interpretation, physician assessment, and consistent administration of ASA. Proportions of these metrics meeting target times have not yet reached our benchmark goals; given our progress to date, this will be possible in the near future. We have also successfully quantified our clinical performance in these areas. Prior to Lean, data collection was inconsistent, as demonstrated by the historical chart review; 59.0% (135 of 229) of pre-Lean MD assessment times and 76.4% (175 of 229) of pre-Lean ASA data points were missing. This presented a major obstacle to accurate evaluation of early ACS care in our ED. Recording of patient arrival, ECG interpretation, physician assessment, and ASA administration times are now built into the standard work of triage nurses and physicians, making it possible to track future performance and identify new problem areas. Post-Lean, documentation of ASA administration improved to 81.4% (1,170 of 1,437). The fact that major improvements in target outcomes were made despite gaps in baseline data is noteworthy.

With regard to ASA administration, staff have speculated that our post-Lean success was much more impressive than our study suggests. Nurses habitually document only those medications they have administered or discussed. This suggests that many of the missing pre-Lean data points may have been cases in which ASA was not given and that the post-Lean success rate of 75.5% represents a significant improvement. Despite this lack of demonstrable improvement in

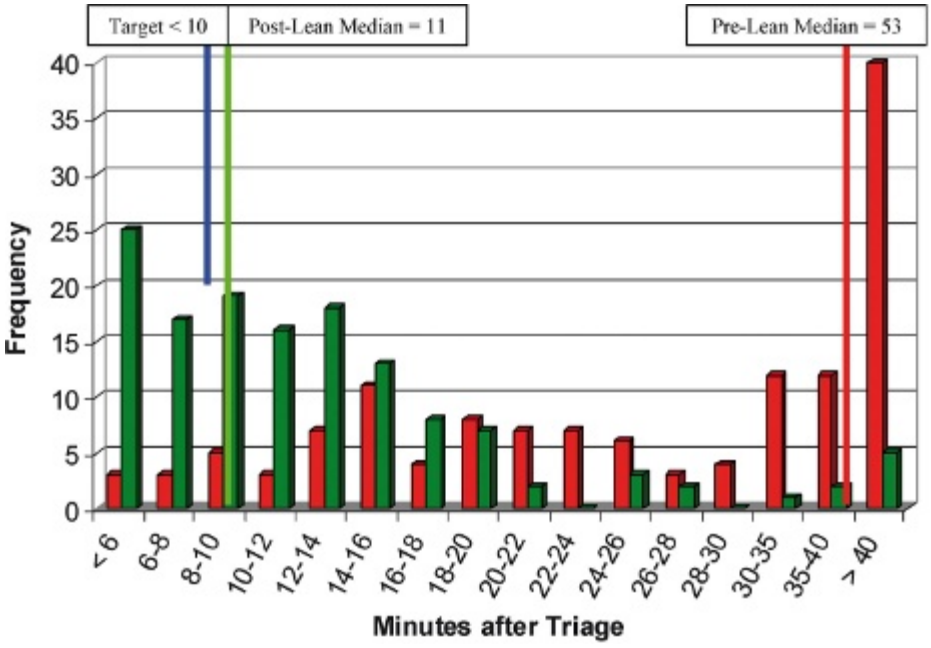

Figure 3. Breakdown of times to first 12-lead electrocardiogram (ECG) pre-Lean (right-most thin line) and 10 months after Lean implementation (September 2009, middle thin line). The frequency with which first ECGs were performed in ≤ 10 minutes increased after the Lean intervention, as shown by median times to ECG. The post-Lean median time in minutes (right-hand side) is approaching the ideal target (left-most thin line).

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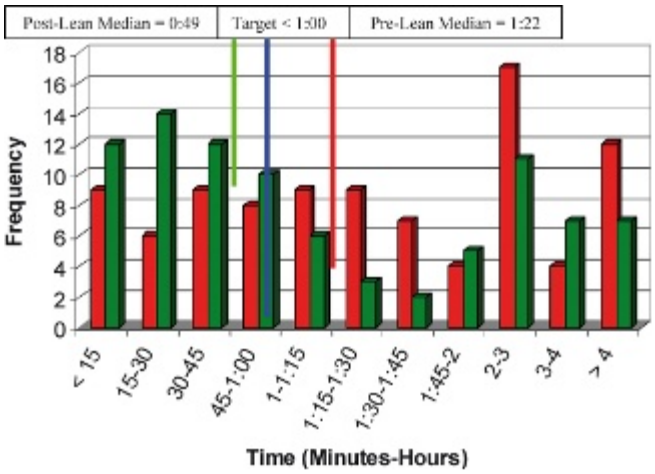

Figure 4. Breakdown of times to physician (MD) assessment pre-Lean (right-most thin line) and 10 months after Lean implementation (September 2009, left-most thin line). The frequency with which suspected acute coronary syndrome patients are assessed in ≤ 60 minutes increased after the Lean intervention, as shown by median times to physician assessment. The post-Lean median time in minutes (right-hand side) has surpassed the target (middle thin line).

documented ASA administration times when compared to our control group, our post-Lean ASA data do show a strongly significant trend of gradual improvement over time, a wholly different parameter. This is consistent with adherence to the Lean tenets of continuous re-evaluation and streamlining after implementation.

By definition, Lean is a dynamic and ongoing process. Data collection forms, personnel responsible for recording relevant times, and ACS care map activation criteria did not remain static throughout the study period. In the months following Lean implementation, it became clear that physician assessment within 60 minutes of arrival was impossible for all suspected ACS cases, given the sheer volume of patients and departmental resource constraints. In February 2009, triage nurses began to further risk-stratify suspected ACS patients as "green," "amber," or "red" based on limited historical and triage parameters. The physician assessment goal of ≤ 60 minutes was thereafter applied to red and amber patients only. This further facilitated early cardiac care for the highest-risk patients while precluding the need to unnecessarily push low-risk patients to the front of the queue. However, all suspected ACS patients still received an early, physician-interpreted ECG.

This application of Lean to early ACS care has highlighted the negative impact of overcrowding and the resulting unacceptable delays in EDs. Our institution has been inspired to continue using Lean, and success need not be limited to the narrow segment of patient care we have described. Current and future areas of ED improvement include early sepsis patients, minor treatment area patients, and direct-to-surgery patients, all of whom may be particularly affected by inefficient care. Other Lean initiatives are already under way elsewhere in our hospital. These include streamlining of supply chains and operating room turnover on the acute care surgery service and unclogging access to Cardiology and Medicine inpatient beds. Such projects have the potential to positively impact patient flow from the ED to other inpatient areas.

LIMITATIONS

Several limitations must be considered when interpreting our results. This study attempted to quantify the impact of a process improvement initiative using a medical research model not designed for a dynamic, continually changing project. As discussed, the routine work of ED personnel, including paperwork handling, and methods of documentation did not remain static throughout the post-Lean study period as we worked to identify and implement processes that were optimal for our working environment. The state of flux of the ED environment may have influenced our findings. In addition, our control group consisted of an unblinded, retrospective chart review completed by the primary author. These patients were selected using only triage complaint, with minimal inclusion or exclusion criteria. This may have resulted in a less homogeneous population than that selected by triage nurses post-Lean. Searching paper records for nonstandardized pieces of information proved to be challenging. Physician assessment and ASA administration (variably and inconsistently documented by nurses and physicians in our charts) accounted for all discordance between the primary and second physician abstractors; we found 100% concordance for ECG times.

CONCLUSIONS

Our study indicates that the application of Lean principles can significantly improve attainment of early diagnostic and therapeutic milestones of emergency cardiac care in the ED, specifically the timeliness of first ECG, ECG interpretation, physician assessment, and

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ASA administration. Lean is best used when institutions apply the basic principles to create solutions unique to their specific challenges. Lean has many possible emergency medicine applications; further study in this area is warranted.

Competing interests: None declared.

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