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Original Contribution

Applying Lean methodologies reduces ED laboratory turnaround times☆,☆☆,★

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ABSTRACT

Background: Increasing the value of health care delivery is a national priority, and providers face growing pressure to reduce cost while improving quality. Ample opportunity exists to increase efficiency and quality simultaneously through the application of systems engineering science.
Objective: We examined the hypothesis that Lean-based reorganization of laboratory process flow would improve laboratory turnaround times (TAT) and reduce waste in the system.
Methods: This study was a prospective, before-after analysis of laboratory process improvement in a teaching hospital emergency department (ED). The intervention included a reorganization of laboratory sample flow based in systems engineering science and Lean methodologies, with no additional resources. The primary outcome was the median TAT from sample collection to result for 6 tests previously performed in an ED kiosk.
Results: After the intervention, median laboratory TAT decreased across most tests. The greatest decreases were found in "reflex tests" performed after an initial screening test: troponin T TAT was reduced by 33 minutes (86 to 53 minutes; 99% confidence interval, 30-35 minutes) and urine sedimentation TAT by 88 minutes (117 to 29 minutes; 99% confidence interval, 87-90 minutes). In addition, troponin I TAT was reduced by 12 minutes, urinalysis by 9 minutes, and urine human chorionic gonadotropin by 10 minutes. Microbiology rapid testing TAT, a "control," did not change.
Conclusions: In this study, Lean-based reorganization of laboratory process flow significantly increased process efficiency. Broader application of systems engineering science might further improve health care quality and capacity while reducing waste and cost.

1. Introduction

Health care costs continue to increase in the United States, and average per capita expenditures represent approximately twice that of other developed nations [1]. Thus, increasing the value of health care delivery is a national priority, and providers are facing growing pressure to reduce cost while improving quality [2,3]. However, while multiple studies and governing bodies have suggested increased utilization of systems engineering science as a potential solution, it is not abundantly clear which tools are the most effective for application in health care [2].

Although this problem is ubiquitous in most areas of medicine, some of the present challenges are of particular importance in emergency medicine. For example, emergency department (ED) crowding remains a national crisis, with myriad and well-documented negative effects on patient care efficiency, quality, and safety, including increased cost, delayed care, and even increased mortality [4-6]. Moreover, the burden of capacity constraints on US EDs is predicted to worsen in the future, likely exacerbating the most destructive current barrier to effective, high-quality care for ED patients in the United States [1,7,8] and underscoring the importance of targeting throughput as an approach to increasing functional capacity. In their 2006 report detailing these challenges, "Hospital Based Emergency Care: At the Breaking Point," the Institute of Medicine recommended that proven innovations in systems science and industrial engineering, which have largely not yet taken hold in the health care delivery sector, be broadly applied to improve the quality and efficiency of emergency care [7]. As a model for further investigation, emergency medicine represents a valuable crucible in which to test theories that may be more broadly applicable.

1.2. Theoretical framework

In terms of systems improvement opportunities, emergency medicine is also an excellent example of an area in health care in which increased patient care efficiency not only decreases waste and cost but also improves quality. This occurs through effects on the quality domains of timeliness, efficiency, effectiveness, and safety. However,

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only recently has the emergency medicine literature started to demonstrate the successes that many similarly complex industries, such as the auto, airline, and service industries, discovered long ago [9-11]. As such, there remains significant opportunity to refine the use and application of these tools across EDs in an ongoing effort to optimize care, especially with respect to modeling and streamlining processes and improving throughput, reducing waste, and creating much needed capacity [12-14].

For example, Lean methodologies, originally designed for use in process improvement in the manufacturing industry, represents a potential tool for improving systems of care and throughput in the ED [15-17]. However, these tools have only minimally been studied in health care as a whole and less so in the ED specifically [18-20].

Although previous observational research has demonstrated the potential for Lean methodologies to reduce hospital ED laboratory turnaround times (TAT) [21,22], we hoped to expand the extant literature, especially given the link between laboratory and other ancillary testing and ED length of stay and capacity [23]. In this study, we used Lean-based systems engineering tools to reorganize laboratory sample flow based in systems engineering science and modeling, with associated reallocation of resources; no resources were added. We sought to optimize the laboratory testing processes, reduce TAT to the extent possible, decrease waste, and begin to quantify the value of such an intervention.

2. Methods

2.1. Study design

This study was a prospective, before-after analysis of laboratory process improvements in a hospital ED and main laboratory. We included all adult patients seen during the study periods of September 2012 to February 2013 (before) and March 2013 to February 2014 (after). Data were extracted from the laboratory information system. A period of 1-year postintervention was chosen to provide an adequate sample size and to assess the sustainability of any observed effects. The intervention occurred on March 4, 2013. Institutional review board approval was obtained for the final data analysis, so that deidentified data could be retrospectively evaluated in the context of a hypothesis-driven study.

2.2. Study setting and population

The study was performed in a large, urban, teaching hospital ED with an annual census of approximately 102 000. The ED serves as a level I trauma center for adult and pediatric patients as well as a regional burn center. The admission rate is approximately 26%, and approximately 31% of all visits arrive by ambulance. Patient flow in the ED follows a relatively standard course with triage, registration, evaluation in a care area, and disposition. Laboratory studies are ordered after initial patient evaluation, and samples are then drawn by nursing and nursing assistant staff. Samples are labeled, a laboratory requisition sheet is completed, and the sample is sent for laboratory testing as described in more detail below.

2.3. Selection of participants

All adult patients seen in the ED on whom applicable laboratory testing was performed were included in the analysis.

2.4. Intervention

The intervention was a focused Lean-based reorganization of laboratory process flow. Preintervention: selected point-of-care laboratory tests (troponin I, urinalysis, and urine human chorionic gonadotropin) were processed and performed in a laboratory located within the ED (the "kiosk"), and results were distributed through the electronic medical record. More specifically with regard to process flow, laboratory samples were either hand carried to the kiosk or placed in specified bins to be collected by the kiosk laboratory technician (Fig. 1).

In the future state intervention, it was determined that all samples would be sent via an existing pneumatic tube system to a reorganized section within the central laboratory of the hospital (Fig. 2). In the reorganized laboratory section, the screening and confirmatory testing platforms were co-localized to facilitate improved reflex testing and communication. Microbiology rapid testing flow did not change significantly in terms of process re-engineering intervention and thus was considered a "control" test.

There were no additions to staffing, nor added resources, during this intervention. In addition, there were no other significant and identifiable operations changes effecting laboratory process flow metrics in either the ED or the main laboratory between the 2 study periods.

2.5. Methods of measurement

The primary outcomes measured were laboratory TAT for individual testing modalities, defined as the time interval between sample collection and final result.

2.6. Data collection and analysis

Data were extracted from the Sunquest laboratory information system (LIS, Tucson, AZ) for both the preintervention and the postintervention periods. Tests were included in the analysis if accessioned at the dedicated ED kiosk computer terminal by the dedicated technologist (identified by a unique LIS location code); as noted, this "virtual" location and terminal were physically within the ED during the preperiod and within the central laboratory during the postperiod. Emergency department testing during the preperiod and postperiod not routed through the dedicated ED kiosk location and workflow was excluded from the analysis. These excluded tests include those not offered by the kiosk and tests not sent using special kiosk requisitions. In addition, testing sent in the preperiod and postperiods using requisitions improperly completed and lacking collection times was excluded from the analysis.

Statistics were performed using the R statistical scripting language [24]. Because TAT were not normally distributed and follow a skewed distribution, medians were used as a measure of central tendency to summarize the distributions. To adjust for multiple testing, Bootstrap resampling was used to calculate empiric 99% confidence intervals (CIs) around the median TAT for each test category before and after the intervention as well as the change in median TAT for each test category. Bootstrap CIs were calculated using the "basic" approach within the R package boot [25]. Two thousand five hundred bootstrap replicates were used to calculate each interval. Bar graphs were generated using the R package ggplots [26].

3. Results

After the intervention, median laboratory TAT decreased significantly across most tests studied (Fig. 3). The greatest decreases were found in reflex tests performed after an initial screening test: troponin T (reflex test for a positive or borderline troponin I test) TAT was reduced by 33 minutes (86 to 53 minutes; 99% CI, 30-35 minutes; n = 722 preintervention and 844 postintervention) and urine sedimentation (reflex test for a positive chemical urinalysis test) TAT by 88 minutes (117 to 29 minutes; 99% CI, 87-90 minutes; n = 6396 preintervention and 13 155 postintervention). In addition, troponin I TAT was reduced by 12 minutes (41 to 29 minutes; 99% CI, 10-13 minutes; n = 3656 preintervention and 4698 postintervention), urinalysis TAT by 9 minutes (29 to 20 minutes; 99% CI, 8-9 minutes; n = 11 470 preintervention and 24 018 postintervention), and urine human chorionic gonadotropin TAT by 10 minutes (28 to 18 minutes; 99% CI,