Utilizing Lean Principles to Improve Immunization Administration Efficiency in a Pediatric Mobile Clinic Program

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Abstract
Introduction: Mobile clinics are vital health care delivery systems because they provide care to those who may not have access otherwise. Unfortunately, clinic flow on mobile clinics is often chaotic and inherently inefficient. Lean is a customer-centric methodology used in industries like health care to continuously improve processes by eliminating waste. The purpose of this project was to use lean principles to improve efficiency, as measured by total time spent receiving services, so that more underserved patients could receive needed immunizations. Methods: Using a certified lean expert, lean principles were applied to the mobile clinic program to uniformly organize the program, simplify registration processes, and standardize clinic procedures. Time study data were collected prospectively on a total of 309 patients for 2-week periods both before and after application of lean principles. Staff used a standardized time study form to record patient visit times. Pre- and postintervention data were analyzed using unpaired t tests and nonparametric Mann-Whitney tests as deemed appropriate. Results: Using lean principles significantly reduced total times spent for 1-, 2-, and 4-children families. Wait times for 1- and 4-children families were also significantly decreased. Lastly, times spent on board the mobile clinic to receive immunizations for 1- and 3-children families were significantly decreased. Conclusion: Application of lean principles can improve efficiency by decreasing total time spent for patients receiving vaccine services on pediatric mobile clinics. (Pediatr Qual Saf 2017;2:e037; doi: 10.1097/pq9.0000000000000037; Published online August 21, 2017.)

INTRODUCTION
Mobile clinics are fully equipped medical clinics in customized motor coaches. There are an estimated 2,000 mobile clinics in the United States. These important health care delivery systems provide medical care to those who lack access to traditional clinics. The majority of mobile clinics provide comprehensive medical care including preventative medicine, primary care, acute care, and dental services. Mobile clinics can help prevent unnecessary emergency room visits, which can decrease health care spending. Mobile clinics have also led to improvement in health outcomes such as reduction of blood pressure and early cancer detection.

Although mobile clinics provide a valuable service, this health care delivery model is inherently inefficient. Daily loading and unloading of equipment, lack of transferable medical records, and long wait times due to limited clinic space contribute to poor patient flow and inefficiency. Additionally, an underserved population, particularly those with language barriers and low health literacy, may require translation services and assistance to complete forms, causing further delays. By improving efficiency, mobile clinics can potentially see more patients and decrease health care spending.

Over the past decade, health care delivery systems have used structured methods such as lean principles to improve the delivery of patient care. Lean is a customer-centric methodology focusing on continuously improving processes by eliminating waste. Value, the key concept in lean, is the ability to deliver the exact customer-requested service with minimal wait time at an appropriate price. By defining “what customers want,” process steps can be divided into value and nonvalue adding. Value adding activities contribute directly to creating a service a customer desires. Nonvalue adding activities do not and are called waste. Waste should be removed...
or avoided. The 5 steps involved with implementation of lean processes are: (1) determine value based on customer desires; (2) identify steps in a process and remove waste; (3) order the remaining steps to create uninterrupted flow toward the customer; (4) pull value based on customer demand; and (5) repeat the first 4 steps in pursuit of a process with zero waste.² Lean principles have been successfully applied to health care in emergency rooms, hospitals, and outpatient clinics.³–¹² Multiple studies have used lean principles in the outpatient setting.¹³–¹⁵ However, to our knowledge, lean principles have not been applied in a mobile clinic setting nor for immunizations.

The purpose of this study was to determine whether applying lean principles to identify problem areas, modify workflow, and eliminate waste in a mobile clinic setting can improve efficiency by shortening the total time patients spent receiving services.

The specific goal of this study was to use lean principles to reduce total time patients spent receiving services on a pediatric mobile clinic by 10% by September 2014.

METHODS

Institutional review board’s approval was not required because the study was a quality improvement project.

Mobile Clinics and Patient Population

The mobile clinic program (MCP) consists of 2 clinics that provide free clinical services to children 0–18 years of age. The mobile clinics drive into the community daily and park at host sites to provide services. Host sites include elementary schools, churches, community centers, and libraries. Although the clinics are parked at a host site, services are available to the general public. When fully staffed, each clinic has 2 medical assistants, 1 nurse practitioner, and 1 pediatrician. All staff members are Spanish/English bilingual.

Families who use the mobile clinic are primarily Spanish or English speaking with a small percentage speaking other languages. For our non-Spanish, non-English patients, a phone translation service is used. Registration forms are provided in English and Spanish. Patients on the MCP, mostly uninsured immigrants, are seen on the mobile clinics for vaccinations, well-child checks, sick visits, and follow-up visits. In 2014, approximately 90% of patients received vaccinations. Thus, only patients seen for vaccine services were included in this analysis. Vaccine services are provided on a first-come, first-served basis.

Data Collection

Preintervention data were collected prospectively from April 28 through May 8, 2014. Between May 9 and September 14, 2014, lean principles were applied. Subsequently, postintervention data were collected prospectively from September 15–25, 2014. In the first data collection period, 208 patients visited the mobile clinics, of which 137 received only vaccine services. Of these, 2 patients were excluded due to incomplete data collection, resulting in 135 patients in the preintervention group. In the postintervention data collection period, 215 patients visited the mobile clinics, of which 185 received only vaccine services. Of these, 13 patients were excluded due to incomplete data collection, resulting in 172 patients in the postintervention group.

All team members used a standardized time study form to record data during the pre- and postintervention periods. To highlight clinical workflow and minimize subjective measures, times recorded included (1) arrival time to mobile clinic; (2) time front desk staff gave family paperwork; (3) time family returned paperwork to front desk; (4) time family came onto the mobile clinic; (5) time seen by physician or nurse practitioner (for patient visits only); (6) time discharged to front desk; and (7) time discharged from the mobile clinic. Demographic information collected included patient gender, age, language spoken at home, and number of children from the family receiving services. Also recorded were patient visit type and number of vaccines administered. The standardized time study form was attached to each patient’s chart, and times were recorded by staff members as the patient progressed through the clinic. To minimize time variability, clinic and staff cell phone clocks were synchronized each morning.

Intervention

After obtaining the preintervention data, a lean-certified expert consultant led staff and leadership in identifying key problem areas and processes that needed streamlining. These processes were grouped into 4 subtopics: (1) evaluating clinic processes; (2) skill/competency development; (3) organizational leadership structure; and (4) evaluating policies. Over a 4-month period, groups containing people from various levels of leadership were assigned 1–2 topics to implement the leaning process. Targeted processes included vaccine visits, registration processes, and creation of standardized operating procedures for all clinic aspects. After mapping out the vaccine process, the lean expert determined that significant time was spent gathering necessary vaccine supplies. This was because the 2 mobile clinics were not stocked identically leading to staff and providers not always knowing where a supply was located on a given clinic. Thus, staff and providers standardized the location of supplies between clinics so that each team member would be equally familiar with both clinics’ layout. After the standardization, photographs were taken of each room on each clinic, and the location of supplies in each room was compared for consistency.

The loading and unloading processes were also evaluated by the lean-certified expert consultant. To maintain patient confidentiality and correct temperature of vaccines, many supplies are loaded and unloaded from the clinic daily. The lean expert determined that each morning, staff were spending extra time walking back and forth gathering necessary supplies. This longer loading time ultimately led to a later clinic start time. Thus, the lean expert helped reorganize location of supplies so that staff would start at
one end of the office and move toward the door as they gathered supplies on their way out to clinic.

Creating standardized operating procedures allowed the entire MCP team to understand how the clinics should operate and also how to disseminate information and report issues. Streamlining the registration process was important because families visiting the mobile clinic often have low health literacy leading to longer times needed to complete paperwork. To have the first patient seen on the mobile clinic earlier, staff members assisted that patient’s caregiver complete registration paperwork. In addition, staff members were asked to help complete paperwork for as many subsequent families as possible. By shortening the registration time, families could be seen earlier leading to improved clinic flow.

**Statistical Analysis**

Analysis was performed on both pre- and postintervention time study data. Times collected were used to calculate the following: (1) total time spent (time discharged from clinic minus arrival time); (2) registration time (time family returned paperwork to front desk minus arrival time); (3) wait time (time families came onto clinic minus time families returned paperwork to front desk); and (4) time in clinic (time discharged from clinic minus time families came onto clinic). Analysis was focused on vaccine-only visits.

Standard statistical analysis was performed using Minitab (v.17; State College, PA), and values of $P < 0.05$ were considered statistically significant. Preliminary analysis of vaccine-only pre- and postintervention data using analysis of variance revealed a statistically significant difference in total time spent depending on the number of children in the family being seen. Therefore, further analysis was done on data subdivided into groups based on number of children seen.

Pre- and postintervention vaccine-only visit data for single-child and 2-child families were analyzed using unpaired $t$ tests. Due to small sample sizes and outlier data points, pre- and postintervention vaccine-only visit data for 3- and 4-child families were analyzed using nonparametric Mann-Whitney tests.

Further analysis was done using box plot and control charts. Data were not subdivided into groups based on the number of children seen because there was insufficient data in each category to run separate control charts.

**RESULTS**

There was no significant difference in demographic data between the pre- and postintervention groups (Table 1).

**Box Plot**

The box plot (Fig. 1) shows significant reduction in total time spent from pre- to postintervention. Both pre- and postintervention data contain a number of outliers. Review of the raw data revealed registration time to be the root cause.

**Control Charts**

The control chart illustrated in Figure 2 reveals that both pre- and postintervention total time spent are out of control. In Figure 2, points 1–26 correspond to preintervention total time spent, whereas points 27–58 correspond to postintervention total time spent. Specifically, points 37–58 correspond to postintervention times after the Nelson rules were met. For total time spent before Nelson rules were met, there are 3 points that fall above the control limits (UCL) and 2 points that fall on or below the lower control limit (LCL). For postintervention total time spent before the Nelson rules are met, there is 1 point that falls above the UCL and no points that fall below the LCL. Review of the raw data reveals that mostly registration time accounted for the points that fall above the UCL. However, in some cases, wait time also caused the points to be out of control. The points that fall at or below the LCL represent ideal conditions where registration and wait time were short. It is important to replicate these conditions for future patients.

The control chart shows 36 points before the Nelson rules are met, with a mean time of 88.6 minutes. After the Nelson rules are met, the process mean decreased to 67.5 minutes. Furthermore, the corresponding centerlines on the s chart show a change from 26.04 minutes to 18.31 minutes, indicating that the process became more consistent. The reduction of the SD is reflected in the narrower control limits in the X-bar chart after the Nelson rules are met.

**Results Subdivided by Number of Children in the Family**

Figure 3 reveals results specifically for single-child vaccine visits. Due to space limitations and small sample sizes for 2-, 3-, and 4-child visits, all results divided by number of children in the family are displayed in Table 2. Overall,
the total time spent significantly decreased after intervention. For single-child visits, the total time spent decreased from 81.0 (95% confidence interval [CI], 10.44–151.56) to 68.7 (95% CI, 9.1–128.3). The total time also decreased significantly for 2-children visits and for 4-children visits with corresponding P values and actual values displayed in Table 2. Average wait time decreased significantly in single-child visits and 4-children visits. Wait times were reduced

![Boxplot of Pre-intervention and Post-intervention Total Time Spent](image1)

**Fig. 1.** Box plot for preintervention total time spent vs. postintervention total time spent.

![Xbar-S Chart of Preintervention and Postintervention Total Time Spent](image2)

**Fig. 2.** Xbar-S Control Chart of preintervention and postintervention total time spent.
in both 2- and 3-children families, but reduction was not statistically significant. Time in clinic decreased significantly in single-child vaccine visits and 3-children families. Time in clinic decreased in 2-children families, but this decrease was not statistically significant. Registration time decreased in all 4 groups, but these results were not statistically significant.

Overall, the average number of patients seen per clinic per day increased from 10.5 in the pre- to 11.6 in the postintervention period. The average number of vaccines given per clinic per day increased from 30 to 40 from the pre- to postintervention periods.

**DISCUSSION**

The purpose of this study was to determine whether applying lean principles in a mobile clinic setting could improve efficiency by shortening total time spent receiving services. To the best of our knowledge, application of lean principles in a mobile clinic environment, which provides mostly immunization services, has not previously been reported. Application of lean principles in this environment is particularly important to maximize access to care for those patients without health insurance, leading to reduction in health care costs by preventing vaccine preventable disease.

By applying lean principles, the clinics were uniformly organized and clinic procedures were standardized leading to decreased total time spent receiving vaccine services, overall and specifically for those families with 1, 2, and 4 children. Wait times on the mobile clinics for families with 1 and 4 children were also significantly decreased. Times in clinic for families with 1 and 3 children were also significantly decreased, but these results were not reproduced with 2- and 4-children families. Registration times for all patients were not significantly decreased after applying lean principles. Despite not decreasing registration times, use of lean principles did improve overall efficiency leading to an increase in both average number of patients seen and average number of vaccines given per day.

Our results are similar to results of other studies using lean principles in the outpatient setting. Lean Six Sigma principles have demonstrated improved efficiency in a tertiary care otolaryngology clinic where there was a significant reduction in patient wait time and improvement in on-time patient examination start time. Another study in an internal medicine clinic utilized lean Six Sigma to reduce wait duration between end of triage and resident patient encounters. Length of total encounters were also decreased using lean principles. A third 3-phase study used lean

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**Table 2. Transit Times Depending on Number of Children in the Family**

| No. of Children in the Family | Total Time Spent | Registration Time | Wait Time | Time in Clinic |
|------------------------------|-----------------|------------------|-----------|---------------|
|                              | Pre: 81.0 (10.44, 151.56)* | Pre: 39.3 (-5.8, 84.4)* | Pre: 24.9 (-25.1, 74.9)* | Pre: 25.0 (-6.2, 56.2)* |
|                              | Post: 68.7 (9.1, 128.3)* | Post: 36.4 (-10.6, 83.4)* | Post: 17.4 (11.6, 46.4)* | Post: 14.9 (-4.1, 33.9)* |
|                              | *P = 0.007       |                   | *P = 0.011  |               |
| 2                            | Pre: 103.8 (24.8, 182.8)* | Pre: 54.2 (4.8, 103.6)* | Pre: 24.2 (-32.8, 81.2)* | Pre: 26.8 (-6.9, 60.5)* |
|                              | Post: 89.5 (17.5, 166.7)* | Post: 48.8 (-23.3, 120.9)* | Post: 18.7 (-11.5, 48.9)* | Post: 22 (0.2, 43.8)* |
|                              | *P = 0.047       |                   | *P = 0.001  |               |
| 3                            | Pre: 105†        | Pre: 72†          | Pre: 28†   | Pre: 22†      |
|                              | Post: 117†       | Post: 60†         | Post: 18†  | Post: 9†      |
|                              | *P = 0.01        |                   | *P = 0.063  |               |
| 4                            | Pre: 164†        | Pre: 90†          | Pre: 25†   | Pre: 15†      |
|                              | Post: 72†        | Post: 42†         | Post: 8†   | Post: 23†     |
|                              | *P = 0.01        |                   | *P = 0.01  |               |

*Mean time (min) and 95% CI.
†Median time (min).
principles to improve the efficiency of adult chemotherapy preparation turnaround times and revealed a decrease in preparation turnaround times after each phase.\textsuperscript{12}

Although our results are similar to studies in other outpatient settings, the mobile clinic setting is very different than an outpatient clinic. One major difference is that mobile clinic services are provided mostly on a walk in basis, whereas outpatient clinics generally appoint patients. Walk-in clinics can see more patients per day, but there are often longer wait times and a chaotic start to clinic when multiple families are waiting when the mobile clinic arrives. Another distinction is that the mobile clinic involves daily loading and unloading of clinic equipment as well as daily set up and cleanup of the clinic itself. Lastly, because of lack of space to store records on the clinics themselves, each patient is treated as a new patient and fills out a new registration packet each time they are seen. This leads to longer registration time. Despite all these challenges, the mobile clinic used lean principles to improve efficiency by decreasing total time patients spent receiving services. Ultimately, this led to an increased average number of both patients seen per day and number of vaccines given.

As previously described, preliminary analysis revealed significant differences in times depending on whether 1, 2, 3, or 4 children in a family were being seen. Thus, analysis was done for each group separately. However, by doing this, the sample sizes for 2-, 3-, and 4-children families were small (Table 1). These small sample sizes led to a low power, which might explain why significant differences were not consistently seen in all groups. Our lack of significant reduction in registration time was due to multiple reasons. Most importantly, the registration process was very difficult to simplify. When this study was implemented, the MCP used paper charts that could not be stored in the clinics. Thus, every patient had to complete an entire registration packet for each visit. Because the registration paperwork could not be simplified due to medical-legal requirements, staff was asked to help families fill out paperwork. In actuality, this occurred only for the first 1 or 2 families each clinic day as the staff had other responsibilities that were vital to later clinic flow. Thus, the effect of lean principles on the registration process itself was minimal. Also, due to the low health literacy level of our patient population, time taken to fill out registration forms was variable and difficult to control.

They lacked significant reduction in registration time they affected times measured. A third limitation was that times were recorded by different individuals throughout a patient’s visit on the mobile clinic. Synchronizing clocks at the start of each clinic day helped correct for this limitation although variations may have still occurred.

**CONCLUSIONS**

Quality improvement using lean principles on 2 pediatric mobile clinics generally decreased total time spent for patients receiving vaccine services, which led to more patients being served and more vaccines administered. Thus, applying lean principles may help reduce total times spent on mobile clinics for preventive medicine visits, allowing more patients to be served. Further studies are warranted to confirm these results with all types of patient encounters and a larger sample size, especially for families with multiple children.

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**DISCLOSURE**

The authors have no financial interest to declare in relation to the content of this article.

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