APPLICATION OF LEAN MANUFACTURING TECHNIQUES IN THE EMERGENCY DEPARTMENT

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Abstract—Background: “Lean” is a set of principles and techniques that drive organizations to continually add value to the product they deliver by enhancing process steps that are necessary, relevant, and valuable while eliminating those that fail to add value. Lean has been used in manufacturing for decades and has been associated with enhanced product quality and overall corporate success. Objectives: To evaluate whether the adoption of Lean principles by an Emergency Department (ED) improves the value of emergency care delivered. Methods: Beginning in December 2005, we implemented a variety of Lean techniques in an effort to enhance patient and staff satisfaction. The implementation followed a six-step process of Lean education, ED observation, patient flow analysis, process redesign, new process testing, and full implementation. Process redesign focused on generating improvement ideas from frontline workers across all departmental units. Value-based and operational outcome measures, including patient satisfaction, expense per patient, ED length of stay (LOS), and patient volume were compared for calendar year 2005 (pre-Lean) and periodically after 2006 (post-Lean). Results: Patient visits increased by 9.23% in 2006. Despite this increase, LOS decreased slightly and patient satisfaction increased significantly without raising the inflation adjusted cost per patient. Conclusions: Lean improved the value of the care we delivered to our patients. Generating and instituting ideas from our frontline providers have been the key to the success of our Lean program. Although Lean represents a fundamental change in the way we think of delivering care, the specific process changes we employed tended to be simple, small procedure modifications specific to our unique people, process, and place. We, therefore, believe that institutions or departments aspiring to adopt Lean should focus on the core principles of Lean rather than on emulating specific process changes made at other institutions. © 2009 Elsevier Inc.

Keywords—Lean; health care; process change; frontline providers; patient satisfaction

INTRODUCTION

In November of 1999, the Institute of Medicine’s (IOM) landmark report To Err Is Human showed that 44,000–98,000 patients die in the United States each year from medical errors (1). In a follow-up report, the IOM called for a fundamental redesigning of America’s health care system with focus on safety and quality (2). These reports did not escape the public’s attention, and since their release there has been a palpable tension between health care systems and purchasers of their services. Patients, third party payors, and the government are now demanding health care delivery systems to be safe, efficient, and quality-driven.

Informed consumers have forced change in a variety of industries, for example, in automobile manufacturing.
Information about automobile safety and quality began to spread in the mid-1960s after the publication of Ralph Nader’s book *Unsafe at Any Speed*, which prompted consumers to demand safer, higher quality cars (3). The constant pressure from informed consumers drove the automobile industry toward improving safety, quality, and the overall value of their products, and is now driving health care in the same direction (4).

As a first step, medical centers that recognize the patient-oriented focus in health care must embrace transparent external reporting of quality and safety information to all interested parties. Next, they need to develop, implement, and sustain process management systems that welcome innovative and creative solutions to the health care delivery processes. These new systems must improve patient and worker safety while enhancing the quality of care and keeping costs down. For a number of institutions this means a re-engineering of their current process management system. According to the IOM, “innovations in industrial engineering that have swept through other sectors of the economy, from banking to air travel to manufacturing, have failed to take hold in health care delivery” (5) (p. 3).

We believe that operations improvement techniques, such as Lean Manufacturing and Six Sigma, which are used in other industries, are well suited to assist health care organizations committed to meeting the challenge (6).

Yet, why have they failed to take hold in health care delivery? First, process improvement techniques are considered core competencies in manufacturing; however, few people in the health care industry are trained and experienced in process improvement methodologies.

Second, there is a lack of goal congruence between physicians and hospitals due to the separation between hospital and physician payment (7,8).

And finally, despite the advances made in patient-driven health care delivery, hospitals fear that shifting the focus to the patient experience will be perceived as shifting the focus away from the physicians and lead to a swing in admissions to “physician-centered” hospitals.

These factors are particularly strong in community practices of primary care and surgery. However, they tend to be less powerful in emergency medicine and academic medical centers where the physician practice plan and the hospital are often owned by the same parent company, making them particularly good candidates for the application of Lean.

THE LEAN PRINCIPLES

“Lean” is a term adopted from Japanese manufacturing defining a philosophy that abhors waste in any form and relentlessly strives to eliminate defects. Waste is defined as any action that does not add value to the product; in health care this refers to the patient experience. Arguably, current health care processes are designed with a focus on the clinicians and how to make them more efficient and minimize their waste. This approach is contradictory to Lean: it is like designing a process with a focus on the factory workers rather than the product they make.

The Lean process evaluates operations step by step to identify waste and inefficiency and then creates new solutions to improve operations, increase efficiency, and reduce expenses. Lean Manufacturing Principles, also referred to as Toyota Production System (TPS), are ubiquitous in the manufacturing environment, especially in the automotive industry. Two basic Lean concepts are: the relentless elimination of waste through standardization of processes and the involvement of all employees in process improvement (9). Empowerment of workers by providing them with the necessary tools to effect changes in their area of work is the cornerstone of the TPS. The two priority duties of the employee’s job then become: a) making the product; and b) finding ways to make the product better by improving quality and flow. Transferred to health care, this means that all clinicians have two jobs: to take care of the patients and to find better ways to take care of patients.

An extremely useful first step in starting Lean is the mapping out of the process using a process map (Figure 1), then assessing the amount of waste in the system using a Value Stream Map (VSM, Figure 2) (10). The VSM documents the time for each process step and quantifies the amount of value-added and no value-added (waste) time in each step. This snapshot of the process helps the improvement team to step back and determine which steps in a process add value to the patient’s experience and which steps take up resources and time and incur cost without adding value. Next, the team determines if each step in the VSM is indeed necessary. The goal is to redesign the process with a new process map that either minimizes or completely eliminates the uncovered waste.

At the center of Lean is product flow. In a Lean assembly line, the product continuously flows with no backlogs, even at the expense of having some downtime for the individual worker. Although the latter may seem like waste, in reality any downtime that occurs as pieces move from station to station is made up for by the reduction of waste in work-in-process inventory and additional movement of partially completed cars that would otherwise stack up. Think of all the extra work that is required for the patients waiting in a bed for an ancillary service, test results, or movement to the floor for admission.
In order for Lean to work effectively, managers must undergo a paradigm shift in considering flow and quality. In the non-Lean environment, managers typically work on reducing costs by constantly improving the efficiency of single processes. In contrast, Lean managers begin by focusing on quality and flow. Once those have been improved at the current staff level, synchronization of staff becomes the focus. Finally, without ever backtracking on quality, flow, or synchronization, Lean managers work on improving the other factors of efficiency. The end result is a much higher-value product than the one produced using a management style focused solely on improving single-step efficiency.

Figure 1. General process map (consolidated to 8 process steps) used to illustrate general Emergency Department flow. A detailed process map (82 process steps) is used by our staff when redesigning processes to improve quality and flow. We also use process maps to communicate changes in work flow to staff.

Figure 2. Example of Value Stream Map (VSM): the VSM is generated after a period of observation during which cycle times (C/T) are measured. The VSM provides the process improvement team with an overview of value added (C/T) and non-value added (waste) activity in a process, which helps them focus on high yield areas and map progress. The VSM is typically used in conjunction with process maps, which are used to redesign individual processes using the suggestions of frontline staff.
Allowing for backlogs to build up would require a plant bigger than one in which a continuous flow system is in place. By focusing on flow and reducing work-in-process inventory, Lean plants tend to take up much less space. Think of all the space in emergency departments used for patients waiting to be seen and treatment areas occupied by patients waiting for a consult, test results, or disposition.

METHODS

Our Emergency Department (ED) is a level one trauma center that saw 37,000 patients in 2006. It is part of a teaching hospital that has about 700 staffed beds and serves as a tertiary referral center for a rural Midwest state. The ED is staffed by 16 faculty and 20 Emergency Medicine residents; it has an admission rate of approximately 30%, with 3% of them going to an intensive care unit.

The first step in instituting Lean was to educate ED managers and other participants involved in a 5-day Kaizen event about Lean principles and techniques. The members of the Kaizen team included two Emergency Physicians, two ED nurses, an ED physician assistant, two physicians from other areas, two radiology technicians, a laboratory technician, five industrial engineers, and five external participants from a local business council. The primary role of the external participants was to define value from a patient perspective. The Kaizen event is one of the fundamentals of Lean; the name denotes an approach to continuous improvement by eliminating activities that don’t add value. A Kaizen event occurs when managers in an organization gather in a workshop to set the base of Lean-driven process changes that would be specific to the organization.

In the next step, each member of the Kaizen team observed ED patient flow and drew a process map of at least one portion of the total flow process, for example, triage, ordering laboratory tests, or admitting ED patients. An example of a limited-detail ED process map is included (Figure 1). During day 1, very specific process maps were drawn and pieced together. Drawing process maps was part of the Lean educational program.

Process mapping was followed by individual process step measurement and value analysis. Value was also part of the Lean educational program. The simplest way to think of value in delivering patient care is to ask the question, “Would the patient be willing to pay for that part of the process only?” As far as patients are concerned, waiting for a laboratory test result or consultant to arrive adds no value, whereas receiving the laboratory test result or consultation adds value. A VSM was then constructed (Figure 2). This map is useful in focusing the team on parts of the overall flow process that have the most waste and, therefore, have the greatest potential to impact overall flow. It was well understood by the Kaizen team that not all waste can be removed from any process and that not all solutions are equally easy to institute.

Day 3 of the Kaizen event focused on generating process improvement ideas from Kaizen team members and frontline caregivers, followed by process redesign. The ideas generated tended to be small and very specific to our ED, for example, standardize and mark the spot where the ultrasound machine goes, put chairs in front of the triage nurse so he/she does not have to walk as far to get patients that have not yet been triaged, and reduce the number of questions asked as part of registration.

Days 4 and 5 focused on new process implementation, refinement, and re-measurement. Although this was the end of the Kaizen event, it was the beginning of our long-term adoption of Lean and a management system in which we are constantly refining and measuring our processes with the goal of delivering greater value to our patients. It should also be noted that, as part of the adoption of Lean, our ED management team had to acknowledge that frontline staff had greater insight into the processes and were, therefore, more likely to find ways of improving them. Frontline staff, in turn, had to understand this paradigm and be encouraged to find solutions to problems that created waste, slowed flow, and decreased the quality of care in our ED.

The process improvements coming from Kaizen were not particularly novel. However, because the staff designed them, they were more enthusiastically accepted and fully deployed. A few examples of new processes instituted in our ED as part of Kaizen and continuing to be part of the new standard operating procedures are:

- Utilization of all examination rooms and immediate placement of patients in the rooms, with bedside registration whenever possible
- A team approach whereby a registered nurse, a resident, and the attending physician get the patient’s history at the same time when possible, thus reducing duplication of history and saving staff time
- Redefined responsibilities of registered nurse, nursing assistant, and intake coordinator
- Laboratory tests/X-ray studies ordering and sending done earlier in the process
- Improved signage for directing patients in and out of the ED
- Identified opportunities for involvement of other services earlier in the process and expedition of admissions.
Average monthly length of stay (LOS), expense per patient, and monthly patient volume were compared by Student’s *t*-test, whereas the percentage of patients ranking the overall ED experience as “Very Good” was compared by chi-squared test. For all outcomes, *p* < 0.05 was considered significant.

**RESULTS**

For the purpose of monitoring our Lean program, we have chosen to monitor the following standard ED operation measures: percentage of patients ranking the overall ED care as “Very Good,” average monthly expenses (nurses, nursing assistants, and other staff working solely in the ED) per patient per month (2005 data were adjusted to 2006 hourly rates secondary to pay changes occurring during the observation period), ED LOS, including admitted patients (~30% of ED volume), and average number of patient visits per month. During calendar years 2005 (pre-Lean) and 2006 (post-Lean) there was no change in the manner in which patient volume, expense, patient satisfaction, and LOS (electronic grease board) were recorded. There were also no significant changes in the number of ED treatment rooms or physician coverage. There was, however, a 4.5% hourly rate increase for nursing personnel; hence, the data are presented normalized to the 2006 rate.

The adoption of Lean in December 2005 has been associated with both short-term and longer-term positive effects on department operations. Immediately after the Kaizen event, we saw an improvement in patient flow with a reduction in average patient LOS, from 161 min in the 3 months before the adoption of Lean, to 148 min in the 3 months after the Kaizen. Despite a statistically significant annual patient visit growth of 9.23% (from 2818 patient visits monthly to 3078; *p* < 0.01) and an admission growth rate of 15% in 2006, adoption of Lean allowed us to sustain our average 2006 LOS (157 min) slightly below the 2005 level (160 min).

Adoption of Lean has also been associated with significant improvement in patient satisfaction. A continuous Press Ganey patient satisfaction survey showed an increase in the percentage of patients ranking the overall ED experience “Very Good” from 54% in 2005 to 59% in 2006 (*p* < 0.01). The significant improvement we experienced in patient flow and patient satisfaction was not associated with a significant increase in inflation-adjusted direct expense per patient (including nurses, nursing assistants, and medical supplies only), which was $121 in 2005 and $124 in 2006.

Our greatest challenge in sustaining the early gains produced by adopting Lean has been to keep up with the growth in patient visits. Interestingly, for 3 weeks after the Kaizen event we never put a patient in the waiting room. Maintaining the specific process improvements that have been implemented since adopting Lean has been relatively easy because they were generated by frontline staff that was performing the process. Although we found the week-long Kaizen event useful as a kickoff to Lean, it has since been replaced with much shorter 2-day events focused on specific process areas, for example, radiology testing of ED patients. During these events and throughout the year, management encouraged staff to make recommendations on how to improve flow and quality and worked to institute the suggestions that have the greatest impact on value.

**DISCUSSION**

Institution of Lean in our ED has been associated with improvements in patient flow, patient satisfaction and, consequently, an increase in patient visits. These changes have been sustainable without increasing expense per patient or the number of ED treatment areas; thus, we believe we have added overall value to the patient experience, mainly because we have employed Lean not as expense-reducing, but as a **value-driven** technique.

The goal of Lean is to constantly increase the value of the product or service delivered. Value is quality of the product or service divided by price. Measuring value in health care is extremely difficult for several reasons: 1) the patient is typically unaware of the price of the product; 2) the patient cannot fully quantify the quality of the service; and 3) the expense that goes into delivering the service can be extremely difficult to measure. Despite the difficulties, it is critical that some objective indicators of value be calculated when assessing the effect of a Lean program for both internal and external purposes.

A key success factor for our program was that management took a subordinate role when it came to solving flow issues and let the frontline staff identify problems and come up with their own solutions. This led to a more empowered staff eager to institute their ideas as opposed to a reluctant staff feeling forced to institute top-down process improvements.

Placing flow ahead of efficiency also was critical to the success of our program. The standard of Lean (first flow, then synchronization, then efficiency) has been heard more and more frequently as Lean principles are becoming part of our culture.

Last but not least, it was not large breakthrough innovations in patient flow that lead to our success but rather multiple small process enhancements idiosyncratic to our unique people, processes, and environment. This led us to believe that it is the principles and not the
specific process changes documented by others that the adopters of Lean should employ.

**CONCLUSIONS**

Lean improved the value of the care we delivered to our patients. Generating and instituting ideas from our front-line providers have been the key to the success of our Lean program. Although Lean represents a fundamental change in the way we think of delivering care, the specific process changes we employed tended to be simple, small procedure modifications specific to our unique people, process, and place. We urge institutions or departments aspiring to apply Lean to focus on the principles we employed and described here rather than on the specific process changes we made.

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**REFERENCES**


**ARTICLE SUMMARY**

1. **Why is this topic important?**
   Emergency Departments (EDs) across the country are struggling to improve patient flow and the quality of care delivered. Lean on a system and ED level can help improve both flow and quality while empowering the frontline caregivers in the ED.

2. **What does this study attempt to show?**
   That adoption of Lean principles improved the value of care delivered and allowed us to move significantly more patients through the ED without increasing length of stay (LOS). Lean was also associated with an increase in patient satisfaction.

3. **What are the key findings?**
   a) An improvement in ED capacity, as is evident by an ability to see significantly more patients without increasing LOS.
   b) An improvement in patient satisfaction with the care received.

4. **How is patient care impacted?**
   a) Patients spend less time waiting for care and are more satisfied with the care they receive.
   b) Staff feel more empowered to make changes and improve care.