APPLYING LEAN TOOLS IN THE CLINICAL LABORATORY TO REDUCE TURNAROUND TIME FOR BLOOD TEST RESULTS

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Abstract- Clinical laboratories are working with almost all clinics in a hospital settlement. They are always expected providing with reliable and on time blood test results by emergency departments, operating rooms, catheterization laboratories and other inpatient clinics. Not only inpatient clinics but also outpatient clinics are demanding time wise since they might be also critical. As a basis of our previous study named “Applying lean six sigma improvement methodology to increase catheterization laboratory efficiency”, we have measured waiting time of patients at each processes from admission until discharge during catheterization laboratory operations. We realized patient-waiting time, late start of first procedures and procedure cancellations are the biggest problems. Pareto analysis has shown that the biggest (30%) contributor of late starts in the cath lab was late blood test results. In this study we aimed reducing blood test delays more than half.

Keywords- Clinical laboratory, Catheterization laboratory, Healthcare, Lean six sigma, Operational efficiency

I. INTRODUCTION

Managing blood test results is a complex process that is critical for patient safety. Lab test errors are among the most frequent in primary care, and are also among the most likely to cascade to patient harm when they occur. (West 2009) Improving how test results are managed and communicated to patients can also help primary care practices achieve savings in staff time and can improve the quality of care they provide. According to West, Improving lab processes are helpful to improve other inpatient and outpatient clinics’ business outcomes. Although it doesn’t look complex, lab operations might be complex and time consuming as West mentioned below:
- Primary care practices handle a large variety of tests that involve both onsite and offsite activities, involving multiple of organizations.
- Tracking tests using reliable metrics is time consuming but critical to ensure that test results have not fallen through the cracks, that appropriate actions have been taken when test results are abnormal, and that patients are informed of their results.
- Processes both before sending samples to the lab and after receiving them back for use require coordination among multiple team members: the clinicians who order tests and act on the results, the medical assistants who complete paperwork and process and track specimens, and the other office staff who route results to the appropriate clinician, file them as necessary, and keep patients informed.

Over two billion laboratory tests are performed annually in the US, predominantly in ambulatory care settings, with errors occurring in more than 20% of all tests - that’s 400 million errors each year. A high volume of lab test ordering occurs in the ambulatory care setting, where pre- and post-analytic processes occur. Communication gaps among providers and staff are major contributors to errors when handling lab tests, which place patients at risk. Many Primary Care offices are working to improve their laboratory testing processes and there is a compelling need to develop performance metrics that will help to understand what impact improvement efforts have in primary care settings. Recent estimates find that the average family physician and general internist orders lab testing in 29% and 38% of patient encounters, respectively. (Hickner 2008) Studies show that 15% to 54% of primary care medical errors reported by primary care physicians and their staff are related to the testing process. (Hickner 2008) Analyses of ambulatory-reported medical errors showed that laboratory testing errors were among the most commonly reported, and were among the types of errors likely to result in some type of harm to patient. (Fernald 2004; West 2009)

Catheter laboratories (Cath Labs) could be one of important but mostly costly area of the hospital although may look like many of determining factors are already known. Analyzing and identifying the root causes of inefficiencies could be challenging if there is not any major problem seen. Improving operational efficiency by eliminating redundancies and streamlining the workflow at the Cath lab and prior the Cath lab starting with outpatient clinic is helpful to reduce different type cost items (Agarwal et al., 2015).

Cath Labs are integral part of hospitals. They are high volume, challenging and complex environments within the hospitals. In a busy Cath lab settlement there is a serious need in efficiency programs that a specialized expert should train hospital staff on how to approach and solve these issues at source. Also between delivering service and commodity there are big differences and difficulties (Bhat, Gijo, & Jnanesh, 2016; Cost, 2009; Fernandes, Daya, Barry, & Palmer, 1994; Tyson, 2010).

As Corbin et al. (2001) presented, Operational inefficiency is ubiquitous to most current healthcare
delivery systems. Some of these operational inefficiencies arise due to impediments and redundancies in the direct medical service delivery process. Others seem to be associated with the logistical, administrative and operational aspects of the healthcare delivery system. Both of these areas are amenable to systematic process innovation and improvement activities. It is well known that improvement in healthcare service quality results in an improvement in patient satisfaction (Corbin, Kelley, & Schwartz, 2001).

Our target and attempt is minimizing blood test waiting time to be able to maximize Cath Lab utilization at each patient pathway. This paper is organized as follows. Section 2 describes our proposed methodology to solve mentioned problems. Case study, computational results and comparisons are presented in Section 3, followed by conclusions in Section 4.

II. METHODOLOGY

2.1. Study Population

This study covers 30 different procedures and majority is elective (80%) than urgent cardiac catheterization (20%) with dominance coronary angiography, coronary angioplasty with BMS, coronary angioplasty with DES, peripheral angiogram, and other heavier procedures performed in between July 2013 and December 2013. Emergency procedures also kept included into study.

2.2. Lean Thinking and Change Management

Lean Thinking principally known as the Toyota Production system, originated by Japanese Automotive industry in 1988 by Ohno and facilitated by the publication of Womack, Jones, and Roos to Western traditions in 1996. Lean is stated in simpler, faster and cheaper solutions and work streams. Also, main assumption is “thinking” or “doing” things in most “effective” and “efficient” way. While lean is more about speed and efficiency and ensures that resources are working on the right and standardized activities, six sigma is more about precision and accuracy and ensures things are done right the first time. LSS is a proven methodology mainly in manufacturing and several industries and also not new its applications in healthcare practices. LSS is essential to establish continuous improvement culture and treating patients with higher quality of care by reducing operational costs and enhancing patient safety in first place (Swartz, Hudson, & Graban, 2013).

This section discusses the methodology adopted for this research. We have used LSS and change management techniques to improve throughput and efficiency. According to data collection plan, data has collected from requesting blood test result from cath lab until receiving the test results for every single blood specimens. Collected data were analyzed using lean tools, decision making and problem solving tools were applied. Current and future Value Streams were mapped (VSM), A3, and Spaghetti diagram were used to analyze data for current and future states. Heijunka (level loading of work and patient demand), 5S, visual management, Mistake proofing, Kanban, Just in time, Pull, Single piece flow, work standardization, layout change are other lean tools used during this study.

We aimed reducing blood test waiting more than half in the context of a busy, challenging and complex Clinical Laboratory workflow setting by using the impact of lean six sigma implementation. Although we focused on the various cycle times impacting efficiency and patient satisfaction components, we have started with priorities and quick wins to start with the journey.

III. CASE STUDY

3.1. Problem Statement

Our one Cath lab city hospital operates under a big health delivery chain. In the year 2012, our Cath lab had 26% increase in procedure numbers with the suburban patients. Cath lab started continually working overtime, cost increased and staff was wearied down. Despite of working long hours, time and effort we spent, and increasing operational cost, our patients were getting increasingly unhappy. Hospital continued treating more patients continually in years 2013 and 2014.

Number of total procedures in our single Cath lab was 1994, 2451, and 3192 in the calendar years 2012, 2013, and 2014. Initial analysis shown that, 324 procedures started with delay out of 1250 cases in the second half of 2013. When we went into delay breakdown that current work stream created were mainly from the “late blood test results” if patient doesn’t have the recent one. Second majority was “procedure rescheduling” during the day since current Cath lab also accepts emergent patients during the day. Third majority was “procedure cancellations” by patients and followed by others as shown in Figure 1.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Before Improvement</th>
<th>After Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood test</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td>Procedure rescheduled</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Procedure cancelled</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>Porter</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>Late finish of previous procedure</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Waiting for material</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>Nurse is late</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Figure 1. Delay break down in cath lab

30% time of total delays were caused because of late blood test results, 97 of the time patients were waited in the cath lab and cath lab team had to reschedule those procedures. 5% of the time in these 97 cases, cath lab stayed idle. In other meaning 5 times there was no cases performed in the cath lab.
When we took into detail of blood test results, especially creatinine test throughput was varying between 180 to 210 minutes in 2013. According to Mayo clinic, generally, a high serum creatinine level means that your kidneys aren't working well. Your creatinine level may temporarily increase if you're dehydrated, have a low blood volume, eat a large amount of meat or take certain medications. The dietary supplement creatine can have the same effect.

If your serum creatinine level is higher than normal, your doctor may want to confirm the results with another blood or urine test. If kidney damage is a concern, it's important to control any conditions that may be contributing to the damage. It's especially important to manage your blood pressure, which often requires medication. You can't undo permanent kidney damage, but with appropriate treatment you may be able to prevent further damage (mayoclinic website)

The purpose of this study is reducing delays in blood test results more than half.

3.2. Understanding and Analyzing the Current State

Data collection and analysis were planned end to end processes starting from sending blood test specimens by cath lab and lab operations until cath lab receives the reliable and validated blood test result.

<table>
<thead>
<tr>
<th>Creatinine Blood Test Delay</th>
<th>Before Improvement</th>
<th>After Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Second half of 2014</td>
<td>Second half of 2015</td>
</tr>
<tr>
<td>Specimen collection</td>
<td>Delay %</td>
<td># of Delay</td>
</tr>
<tr>
<td></td>
<td>60%</td>
<td>27</td>
</tr>
<tr>
<td>Specimen receiving</td>
<td>11%</td>
<td>26</td>
</tr>
<tr>
<td>Repeating test</td>
<td>12%</td>
<td>24</td>
</tr>
<tr>
<td>During test</td>
<td>11%</td>
<td>23</td>
</tr>
<tr>
<td>Other</td>
<td>4%</td>
<td>8</td>
</tr>
</tbody>
</table>

Clinical lab specimens delayed in multiple stages as shown in Figure-2. These are mainly delay during specimen collection (60%), specimen receiving (13%), repeating test (12%), during test (11%) and others (4%).

Delay during specimen collection represents the time spent until collected by clinical lab. Specimen receiving represents that specimens are located into special addresses when they arrived to lab. Sometimes cardiologists may ask repeating test if the result is higher.

After understanding the sources of wastes (non value added activities), we planned and deployed lean techniques.

3.3. Improvement

After initial assessment and analyzing data gathered from the continuous work stream, we applied lean methodology and finalized mapping future state after waste eliminated from the system. Following baseline measurements, KPIs were set. Main lean tools applied. Applied main lean tools were 5S, change management, heijunka, pull, mistake proofing, single piece flow, JIT, layout change. Figure 3 shows initially drafted overlook to lean tools will be applied.

Once the future state was mapped, during the execution step we have planned improvement actions to be able to reduce overall delays in more than half. Analysis was shown that 60% time of delays occurred between when specimen sent until technician put it in order to process.

We analyzed collected data to understand the work load and time slots that represents pick hours and time spent for each activity in clinical laboratory.

Chandelier method applied for us to be able to analyze activities performed by lab staff as shown in Table 1 and Table 2. Tertiary activities have to be performed once a day or once a week and testing can not take place before the specific activity is finished.

Below is some of the main actions and mindset we used during this project.

Reduction errors and variability via planning: As Womack & Jones (1996) has explained, to be able to see if activity can be avoided, we use types of waste as; overproduction, over processing, inventory, waiting, transportation, latent talent, motion and defects. If the activity contains one of these forms of waste it could be an activity potentially has to be avoided. The question asked was
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Reduced batch sizes: Clinical lab has started receiving blood specimens from “as is” instead of batching
Leveraged demand and work load: Staffing schedules matched with blood specimens. 07:00-08:00 is pick hours as we measured
Reduced transportation time of specimens to lab: Cath lab has connected to “chute system”. After implementing “chute system”, transportation time reduced from 5mins to 1 min

Training of cath lab nurses: Activities like registration blood specimens and re-performing test takes time by clinical staff since it’s supply is not optimal and main errors here is wrong tops for tubes or wrong labeling. To reduce this, cath lab nurse has started labeling the specimens.
Priority system: Patient preparation nurses at wards started showing visually the urgency of specimens which needs to be treated first by technician. For this reason, Cath lab nurse started putting an orange sticker on the specimen showing this has to be treated urgently. Otherwise the rest of cath lab blood test specimens started being treated with moderate level urgency unless there is an orange color sticker on it.

Better communication: Between Cath lab and clinical laboratory staff started informing each other incase lab is reworking on the specimen
Work area was organized: 5S was applied to eliminate clutters at front-end. Below is an before/after case

### Table 1. Activity categories and their connection to type of waste

<table>
<thead>
<tr>
<th>Waste</th>
<th>Description</th>
<th>Solution</th>
<th>Potential reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting</td>
<td>Support staff from clinical lab to become available to pick specimens, Batching of specimens in the lab</td>
<td>Cathlab staff hands-off the specimen to clinical lab, identifying responsibilities, Stop batching and create single flow, Planning pick time in the lab, work leveraging</td>
<td>Unorganized work structure, Mixing rate and priority order, Instant and over work load</td>
</tr>
<tr>
<td>Motion</td>
<td>Unorganized work spaces and inventory, Inventory checking</td>
<td>5S, work cell design, Proper inventory management</td>
<td>Tech leaves the work area for several reasons, Poor supply replenishment model</td>
</tr>
<tr>
<td>Inventory</td>
<td>Lack of raw material supply</td>
<td>Inventory management</td>
<td>Long lead time of supplies</td>
</tr>
<tr>
<td>Defect</td>
<td>Work contains mistake or duplication, Lack of performance monitoring, Data entry error, Duplicate work, Re-test, redone, Mixing samples</td>
<td>Work standardization, Mistake proofing,visual control, work silos, poor equipment service, KPI setting and Performance dashboards</td>
<td>Unstandardized work, lack of focus, inaccurate information, Errors</td>
</tr>
<tr>
<td>Over processing</td>
<td>Repeated errors, Lack of standard work</td>
<td>Work standardization</td>
<td>Work silos, lack of visual control</td>
</tr>
<tr>
<td>Over production</td>
<td>More information than needed, Faster and slower pace</td>
<td>Pull system, heijunka</td>
<td>Unbalanced work stream, Push system</td>
</tr>
<tr>
<td>Mis-utilization of skills</td>
<td>Not matched with process improvement</td>
<td>Work load leveraging and engagement</td>
<td>Undersstaffed work area</td>
</tr>
<tr>
<td>Material movement</td>
<td>Wasted motion into lab</td>
<td>Layout organization</td>
<td>Specimens were travelling throughout the lab</td>
</tr>
</tbody>
</table>

### Table 2. Activity categories and their connection to created value

<table>
<thead>
<tr>
<th>Type of activity</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary activities</td>
<td>Everything that has to be done during test</td>
</tr>
<tr>
<td>Secondary activities</td>
<td>Everything that has to be done before or after test</td>
</tr>
<tr>
<td>Tertiary activities</td>
<td>Everything that is directly necessary for testing, but not for every single test</td>
</tr>
<tr>
<td>Quotarian activities</td>
<td>Everything that is directly necessary for testing, but does not create value for the patient</td>
</tr>
<tr>
<td>Quotarian activities</td>
<td>Everything that does not create any value for the patient</td>
</tr>
</tbody>
</table>

**Figure 3. An overview to deployed lean tools**

**Figure 4. priority communication**

**Figure 5. A sample for 5S application**
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Initial scope was not improving lab operations itself, however, we have measured the time spent solving some major bottlenecks in the lab that creates delays in delivering test results. Continuously, we aimed to reduce waste over 90% from overall cath lab operations in years. Performance management of the current Cath lab was also improved by hiring “Cath lab efficiency manager” with responsible of overall efficiency improvement and performance monitoring and leading procedure and material management committee at the hospital. Other hire titled as “material analyst” also permanently joined improvement activities with responsibility of reducing material and supplier related inefficiencies.

CONCLUSIONS AND FUTURE WORK

In this study Lean Six Sigma techniques were used to reduce delays in blood test results requested for cath lab patients. According to our earlier study “Applying lean six sigma improvement methodology to increase catheterization laboratory efficiency”, we have measured waiting time of patients at each processes from admission until discharge during catheterization laboratory operations. We realized patient-waiting time, late start of first procedures and procedure cancellations are the biggest problems. Pareto analysis has shown that the biggest (30%) contributor of late starts in the cath lab was late blood test results.

97 delayed test results out of 324 were resulted as late start because of late blood test results requested by cath lab nurse. Especially creatinine test was varying between 180 to 210 minutes in 2013. To 90 mins Number of blood test delays was 97 before the improvement and reduced to 29 after deploying several improvements.

Initially we have expected;
- increasing patient satisfaction
- increasing cath lab utilization
- better procedure run during the day
- better planned length of stay
- reducing alternative cost spent during blood test waiting time
- reducing time spent for rescheduling of procedure

After a serious of improvements we were able to reduce blood test related waiting time (waste) in more than half from the system

Main deliverable was increasing patient satisfaction by reducing waiting times and also improving overall efficiency of cath lab.

Improving highest rate bottleneck by using impact of lean six sigma methodology effected on improving patient flow, cath lab utilization, capacity freeing up, full time employee utilization, equipment up time, material and staff over time cost in positive way.
For the future work we will be continuously improving overall cath lab operations by reducing wastes.

REFERENCES


